ATS-SDK User Guide

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CHAPTER

ONE

GETTING STARTED

Introduction

AlazarTech supplies device drivers for Windows and Linux that allow software to configure AlazarTech digitizers, and transfer sample data from the digitizer to application buffers.

The AlazarTech software developer's kit (ATS-SDK) includes header and library files required to call functions exported by these device drivers in user written applications, as well as documentation and sample code describing how to use these functions.

This document is a part of the ATS-SDK. It describes how to call functions exported by AlazarTech device drivers to control one or more digitizer boards. It is divided into the following sections:

- A programming guide that describes how to configure, and acquire data from, digitizer boards.
- A reference guide that describes the functions exported by the device drivers.

To get the most from your AlazarTech digitizer:

- Read the user manual supplied their digitizer board. It provides an overview of the digitizer hardware, as well as detailed specifications.
- Read the "Programmer's guide" section of this document. It describes how to program the digitizer hardware to make an acquisition, and to transfer sample data into application buffers.
- Browse the SDK sample programs. They include sample code that demonstrates how to make many types of acquisitions supported by the digitizer.

Note that this document includes descriptions of board specific features and options that may not be available on your digitizer board. Please refer your board's user manual for its specifications.

Programming Environments

C/C++ Linux

C/C++ developers under Linux should include the following header files in source files that use functions exported by the ATS-SDK library:

```
#include "AlazarError.h"
#include "AlazarApi.h"
#include "AlazarCmd.h"
```

These modules should also link against libATSApi.so.

The development package for Linux defaults to installing the header files in /usr/local/AlazarTech/include, and the library files in the standard library directory for the target distribution.

C/C++ Windows

C/C++ developers should include the following header files in source files that use functions exported by the API library:

```
#include "AlazarError.h"
#include "AlazarApi.h"
#include "AlazarCmd.h"
```

These applications should also link against the 32- or 64-bit version of ATSApi.lib, as required.

The SDK setup program installs the header files in "Samples_C\Include", and the library files in "Samples_C\Library".

C#

C# developers should either:

- Add the file AlazarApi.cs to their project; or
- Add a reference to AlazarApiNet.dll to their project.

The ATS-SDK includes a wrapper class that declares many of the constants and unmanaged functions exported by AlazarTech device drivers. This class is provided both as a C# source file (AlazarApi.cs), and as a compiled assembly (AlazarApiNet.dll).

The SDK setup program copies AlazarApi.cs to the "Samples_CSharp\AlazarApiNet\AlazarApiNet" directory and AlazarApiNet.dll to the "Samples_CSharp" directory.

Note that you can use the solution "Samples_CSharp\AlazarApiNet" to build AlazarApiNet.dll from AlazarApi.cs.

LabVIEW

LabVIEW developers can either:

- Use the sub-VIs provided with the ATS-SDK (recommended)
- Call functions from ATSApi.dll directly using the LabVIEW interface for shared libraries.

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The ATS-SDK sub-VIs consists of a very thin wrapper on top of the functions exported by the ATS-SDK. The VIs are named after the functions that they wrap. They are located in "Samples_LabVIEW\Library", and are used by all the code samples available in "Samples_LabVIEW".

The only difference between the connector panes of the VIs and the C function signatures is that an error cluster is propagated through the VIs. If the input error cluster contains an error, the VI simply returns without doing anything.

The error cluster output depends on the function:

- If the function does not generate errors, the input error cluster is simply propagated to the output.
- If the function returns an error code, it is converted to a cluster and send to the output
- If the function can return errors using special return values, then these errors are detected by the VI, an appropriate error code is generated, converted to a cluster and sent to the output

Python

Python developers can use the atsapi.py module provided in the "Samples_Python\Library" directory. It provides a very thin wrapper around the AlazarTech C/C++ API, with only minor differences:

- The 'Alazar' prefixes have been removed from the function names, and the first letter is not capitalized. For example, 'AlazarAbortAsyncRead' becomes 'abortAsyncRead'.
- Board handles have been removed. Instead, a Board class has been added. All the functions that take a board handle as a parameter are moved to being member functions of the Board class.
- A DMABuffer convenience class has been added, that takes care of memory allocation of DMA transfers.
- Some functions of the API use return parameters to give back to the caller primitive types. In Python, the signature of these functions is changed so that the return parameters are replaced with return types.

MATLAB

MATLAB developers can:

- Call functions exported by AlazarTech drivers DLL directly from MATLAB scripts and functions using the MATLAB 'calllib' function.
- Create a MEX-file dynamic link library to configure and acquire data from the digitizer, and call the mexFunction entry point of the DLL from MATLAB.

ATS-SDK samples demonstrate how to use the MATLAB "calllib" interface. They use prototype files to load the AlazarTech driver library into memory, and call AlazarDefs.m to define constants used by the AlazarTech library.

The ATS-SDK setup program installs AlazarDefs.m, alazarLoadLibrary.m, and other helper functions in the "Samples_MATLAB\Include" folder.

C++/CLI

C++/CLI programmers should include a reference to "Samples_CSharp\AlazarApiNet.dll" in their solutions. This assembly provides a .NET interface to the functions and constants defined in the ATS-SDK.

The ATS-SDK does not currently include C++/CLI sample code. See the C# samples for .NET sample code.

Sample code

ATS-SDK includes sample programs that demonstrate how to configure and acquire data from AlazarTech digitizers.

The SDK setup program installs the sample programs to "C:\AlazarTech\ATS-SDK\%API_VERSION%" under Microsoft Windows, and "/usr/local/AlazarTech" under Linux. See the "ReadMe.htm" file in the ATS-SDK base directory for a description of the samples included.

Sample programs are available for the following programming environments in the following sub-directories:

Language	Sub-directory
C/C++	Samples_C
C#	Samples_CSharp
MATLAB	Samples_MATLAB
LabVIEW	Samples_LabVIEW
Python	Samples_Python

Note: Note that the sample programs contain many parameters that should be modified. These lines of code are preceded by "TODO" comments. Please search for these lines and modify them as required for your application.

Warning: Many sample programs require a trigger input. These sample programs configure a board to trigger when a signal connected to its CH A rises through 0V. Before running these samples, connect a 1 kHz sine waveform of amplitude about 90% of the board's input range from a function generator to the CH A connector, or modify trigger parameters as required. For example, the ATS9360 has an input range of +/- 400 mV. For this board, a sine wave of 700 mVpp is appropriate. If an appropriate trigger signal is not supplied, these samples will fail with an acquisition timeout error.

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Contacting us

Contact us if you have any questions or comments about this document, or the sample code.

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Note that you can download the latest drivers and documentation from our web site.

http://www.alazartech.com/support/downloads.htm

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CHAPTER

TWO

PROGRAMMER'S GUIDE

Addressing a board

Getting a board identifier

AlazarTech organizes its digitizer boards into "board systems". A board system is a group of one or more digitizer boards that share trigger and clock signals. To create a "board system" comprised of two or more boards, the boards need to be connected together using an AlazarTech SyncBoard. All of the channels in a board system trigger and are sampled simultaneuously.

ATS-SDK assigns a "system identifier" number to each board system. The first system detected is assigned system ID number of 1. In addition a "board identifier" number is assigned to each board in a board system. This number uniquely identifies a board within its board system.

- If a digitizer board is not connected to any other boards using a SyncBoard, then the SDK assigns it a board ID of 1.
- If two or more boards are connected together using a SyncBoard, then the SDK assigns each board an ID number that depends on how the board is connected to the SycnBoard. The board connected to the "master" slot on the SyncBoard is the master board in the board system, and is assigned a board ID number of 1.

Call the `AlazarNumOfSystems()` function to determine the number of board systems detected by the SDK, and call the `AlazarBoardsInSystemBySystemID()` function to determine the number of boards in the board system specified by its system identifier. The following code fragment lists the system and board identifiers of each board detected by the device drivers:

```
U32 systemCount = AlazarNumOfSystems();
for (U32 systemId = 1; systemId <= systemCount; systemId++) {
  U32 boardCount = AlazarBoardsInSystemBySystemID(systemId);
  for (U32 boardId = 1; boardId <= boardCount; boardId++) {
    printf("Found SystemID %u Board ID = %u\\n", systemId, boardId);
  }
}
```

Getting a board handle

ATS-SDK associates a handle with each digitizer board. Most functions require a board handle as a parameter. For example, the AlazarSetLED() function allows an application to control the LED on the PCI/PCIe mounting bracket of a board specified by its handle.

Use the AlazarGetBoardBySystemID() API function to get a handle to a board specified by its system identifier and board identifier numbers.

Single board installations

If only one board is installed in a computer, ATS-SDK assigns it system ID 1 and board ID 1. The following code fragment gets a handle to such a board, and uses this handle to toggle the LED on the board's PCI/PCIe mounting bracket:

```
// Select a board
U32 systemId = 1;
U32 boardId = 1;

// Get a handle to the board
HANDLE boardHandle = AlazarGetBoardBySystemID(systemId, boardId);

// Toggle the LED on the board's PCI/PCIe mounting bracket
AlazarSetLED(boardHandle, LED_ON);
Sleep(500);
AlazarSetLED(boardHandle, LED_OFF);
```

Multiple board installations

If more than one board is installed in a PC, the boards are organized into board systems, and are assigned system and board identifier numbers. The following code fragment demonstrates how to obtain a handle to each board in such an installation, and use the handle to toggle the LED on the board's PCI/PCIe mounting bracket:

```
U32 systemCount = AlazarNumOfSystems();
for (U32 systemId = 1; systemId <= systemCount; systemId++) {
  U32 boardCount = AlazarBoardsInSystemBySystemID(systemId);
  for (U32 boardId = 1; boardId <= boardCount; boardId++) {
    printf("SystemID %u Board ID = %u\\n", systemId, boardId);

    // Get a handle to the board
    HANDLE handle = AlazarGetBoardBySystemID(systemId, boardId);

    // Toggle the LED on the board's PCI/PCIe mounting bracket
    AlazarSetLED(handle, LED_ON);
    Sleep(500);
    AlazarSetLED(handle, LED_OFF);
  }
}
```


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System handles

Several ATS-SDK functions require a "system handle". A system handle is the handle of the master board in a board system.

- If a board is not connected to other boards using a SyncBoard, then its board handle is the system handle.
- If a board is connected to other boards using a SyncBoard, then the board that is connected to the master connector on the SyncBoard is the master board, and its board handle is the system handle.

Closing a board handle

ATS-SDK maintains a list of board handles in order to support master-slave board systems. The SDK creates board handles when it is loaded into memory, and destroys these handles when it is unloaded from memory. An application should not need to close a board handle.

Using a board handle

ATS-SDK includes a number of functions that return information about a board specified by its handle. These functions include:

`AlazarGetBoardKind()` Get a board's model from its handle.

`AlazarGetChannelInfo()` Get the number of bits per sample, and on-board memory size in samples per channel.

`AlazarGetCPLDVersion()` Get the CPLD version of a board.

`AlazarGetDriverVersion()` Get the driver version of a board.

`AlazarGetParameter()` Get a board parameter as a signed 32-bit value.

`AlazarGetParameterUL()` Get a board parameter as an unsigned 32-bit value.

`AlazarQueryCapability()` Get a board capability as an unsigned 32-bit value.

The sample program "%ATS_SDK_DIR%\Samples\AlazarSysInfo" demonstrates how get a board handle, and use it to obtain board properties. The API also exports functions that use a board handle to configure a board, arm it to make an acquisition, and transfer sample data from the board to application buffers. These topics are discussed in the following sections.

Resetting a board

The ATS-SDK resets all digitizer boards during its initialization procedure. This initialization procedure automatically runs when the API library is loaded into memory.

- If an application statically links against the API library, the API resets all boards when the application is launched.

- If an application dynamically loads the API library, the API resets all boards when the application loads the API into memory.

Warning: Note that when an application using the API is launched, all digitizer boards are reset. If one application using the API is running when a second application using the API is launched, configuration settings written by the first application to a board may be lost. If a data transfer between the first application and a board was in progress, data corruption may occur.

Configuring a board

Before acquiring data from a board system, an application must configure the timebase, analog inputs, and trigger system settings of each board in the board system.

Timebase

The timebase of the ADC converters on AlazarTech digitizer boards may be supplied by:

- Its on-board oscillators.
- A user supplied external clock signal.
- An on-board PLL clocked by a user supplied 10 MHz reference signal.

Internal clock

To use on-board oscillators as a timebase, call `AlazarSetCaptureClock()` specifying `INTERNAL_CLOCK` as the clock source identifier, and select the desired sample rate with a sample rate identifier appropriate for the board. The following code fragment shows how to select a 10 MS/s internal sample rate:

```
AlazarSetCaptureClock(handle, // HANDLE -- board handle
                      INTERNAL_CLOCK, // U32 -- clock source Id
                      SAMPLE_RATE_10MSPS, // U32 -- sample rate Id or value
                      CLOCK_EDGE_RISING, // U32 -- clock edge Id
                      0 // U32 -- decimation
                      );
```

See `AlazarSetCaptureClock()` or the board reference manual for a list of sample rate identifiers appropriate for a board.

External clock

AlazarTech boards optionally support using a user-supplied external clock signal input to the ECLK connector on its PCI/PCIe mounting bracket to clock its ADC converters.

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To use an external clock signal as a timebase, call AlazarSetCaptureClock() specifying SAMPLE_RATE_USER_DEF as the sample rate identifier, and select a clock source identifier appropriate for the board model and the external clock properties. The following code fragment shows how to configure an ATS460 to acquire at 100 MS/s with a 100 MHz external clock:

```
AlazarSetCaptureClock(handle, // HANDLE -- board handle
                      FAST_EXTERNAL_CLOCK, // U32 -- clock source Id
                      SAMPLE_RATE_USER_DEF, // U32 -- sample rate Id or value
                      CLOCK_EDGE_RISING, // U32 -- clock edge Id
                      0 // U32 -- decimation
                      );
```

See the board reference manual for the properties of an external clock signal that are appropriate for a board, and AlazarSetCaptureClock() for a list of external clock source identifiers.

External clock level

Some boards allow adjusting the comparator level of the external clock input receiver to match the receiver to the clock signal supplied to the ECLK connector. If necessary, call AlazarSetExternalClockLevel() to set the relative external clock input receiver comparator level, in percent.

AlazarSetExternalClockLevel(handle, // HANDLE — board handle level_pecent, // float — exernal clock level in percent);

10 MHz PLL

Some boards can generate a timebase from an on-board PLL clocked by user supplied external 10 MHz reference signal input to its ECLK connector.

ATS660

In 10 MHz PLL external clock mode, the ATS660 can generate a sample clock between 110 and 130 MHz, in 1 MHz, steps from an external 10 MHz reference input. Call AlazarSetCaptureClock() specifying EXTERNAL_CLOCK_10MHz_REF as the clock source identifier, the desired sample rate between 110 and 130 MHz in 1 MHz steps, and a decimation factor of 1 to 100000. Note that the decimation value should be one less than the desired decimation factor. The following code fragment shows how to generate a 32.5 MS/s sample rate (130 MHz / 3) from a 10 MHz PLL external clock input:

```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  130000000, // U32 - sample rate Id or value
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  2 // U32 - decimation value
  );
```

ATS9325

In 10 MHz PLL external clock mode, the ATS9325 generates a 500 MHz sample clock from an external 10 MHz reference input. The 500 MS/s sample data can be decimated by a factor of 2, 4, or any multiple of 5.

Call `AlazarSetCaptureClock()` specifying `EXTERNAL_CLOCK_10MHz_REF` as the clock source and 500 MHz as the sample rate, and select a decimation factor of 2, 4, or any multiple of 5 up to 100000. For example, the following code fragment shows how to generate a 100 MS/s sample rate (500 MHz / 5) from a 10 MHz external clock input:

```
AlazarSetCaptureClock(
  handle, // HANDLE -- board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 -- clock source Id
  500000000, // U32 -- sample rate Id
  CLOCK_EDGE_RISING, // U32 -- clock edge Id
  5 // U32 -- decimation
  );
```

ATS9350/ATS9351

In 10 MHz PLL external clock mode, the ATS9350 and ATS9351 generate a 500 MHz sample clock from an external 10 MHz reference input. The 500 MS/s sample data can be decimated by a factor of 1, 2, 4, or any multiple of 5. Call `AlazarSetCaptureClock()` specifying `EXTERNAL_CLOCK_10MHz_REF` as the clock source and 500 MHz as the sample rate, and select a decimation factor of 1, 2, 4, or any multiple of 5 up to 100000. For example, the following code fragment shows how to generate a 100 MS/s sample rate (500 MHz / 5) from a 10 MHz external clock input:

```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  500000000, // U32 - sample rate Id
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  5 // U32 - decimation
  );
```

ATS9360

In 10 MHz PLL external clock mode, the ATS9360 can generate any sample clock frequency between 300 MHz and 1800 MHz that is a multiple of 1 MHz. Call `AlazarSetCaptureClock()` specifying `EXTERNAL_CLOCK_10MHz_REF` as the clock source identifier, the desired sample rate between 300 MS/s and 1800 MS/s, and 1 as the decimation ratio. The sample rate must be a multiple of 1 MHz. For example, the following code fragment shows how to generate a 1.382 GS/s sample clock from a 10 MHz reference:

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```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  1382000000, // U32 - sample rate
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  1 // U32 - decimation
  );
```

ATS9371

In 10 MHz PLL external clock mode, the ATS9371 can generate any sample clock frequency between 300 MHz and 1000 MHz that is a multiple of 1 MHz. Call AlazarSetCaptureClock() specifying EXTERNAL_CLOCK_10MHz_REF as the clock source identifier, the desired sample rate between 300 MS/s and 1000 MS/s, and 1 as the decimation ratio. The sample rate must be a multiple of 1 MHz. For example, the following code fragment shows how to generate a 882 MS/s sample clock from a 10 MHz reference:

```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  882000000, // U32 - sample rate
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  1 // U32 - decimation
  );
```

ATS9373

In 10 MHz PLL external clock mode, the ATS9373 can generate any sample clock frequency between 500 MHz and 2000 MHz that is a multiple of 1 MHz in either single or dual channel mode. In addition, it can generate any sample clock frequency between 2000 MHz and 4000 MHz that is a multiple of 2 MHz in single channel mode.

Call AlazarSetCaptureClock() specifying EXTERNAL_CLOCK_10MHz_REF as the clock source identifier, the desired sample rate between 300 MS/s and 4000 MS/s, and 1 as the decimation ratio. The sample rate must be a multiple of 1 MHz in dual channel if the frequency is less than or equal to 2000 MHz, and a multiple of 2 MHz if the frequency is above 2000 MHz. For example, the following code fragment shows how to generate a 1.382 GS/s sample clock from a 10 MHz reference:

```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  1382000000, // U32 - sample rate
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  1 // U32 - decimation
  );
```

ATS9440

In 10 MHz PLL external clock mode, the ATS9440 can generate either a 125 MHz or 100 MHz sample clock from an external 10 MHz reference input. The 125 MS/s or 100 MS/s sample data can be decimated by a factor of 2, 4, or any multiple of 5.

Call AlazarSetCaptureClock() specifying EXTERNAL_CLOCK_10MHz_REF as the clock source either 125 MHz or 100 MHz as the sample rate, and select a decimation radio between 1 and 100000. For example, the following code fragment shows how to generate a 25 MS/s sample rate (125 MHz / 5) from a 10 MHz external clock input:

```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  125000000, // U32 - sample rate Id
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  5 // U32 - decimation
  );
```

ATS9462

In 10 MHz PLL external clock mode, the ATS9462 can generate a sample clock between 150 and 180 MHz in 1 MHz steps from an external 10 MHz reference input. Sample data can be decimated by a factor of 1 to 100000.

Call AlazarSetCaptureClock() specifying EXTERNAL_CLOCK_10MHz_REF as the clock source, the desired sample rate between 150 and 180 MHz in 1 MHz steps, and the decimation factor of 1 to 100000. Note that the decimation value should be one less than the desired decimation factor. For example, the following code fragment shows how to generate a 15 MS/s sample rate (150 MHz / 10) from a 10 MHz external clock input:

```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  150000000, // U32 - sample rate Id or value
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  9 // U32 - decimation value
  );
```

ATS9625/ATS9626

In 10 MHz PLL external clock mode, the ATS9625/ATS9626 can generate a 250 MHz sample clock from an external 10 MHz reference input. Sample data can be decimated by a factor of 1 to 100000.

Call AlazarSetCaptureClock() specifying EXTERNAL_CLOCK_10MHz_REF as the clock source, 250 MHz has the sample rate value, and a decimation ratio of 1 to 100000. For example, the following code fragment shows how to generate a 25 MS/s sample rate (250 MHz / 10) from a 10 MHz external clock input:

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```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  250000000, // U32 - sample rate Id or value
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  10 // U32 - decimation value
  );
```

ATS9850

In 10 MHz PLL external clock mode, the ATS9850 generates a 500 MHz sample clock from an external 10 MHz reference input. The 500 MS/s sample data can be decimated by a factor of 1, 2, 4, or any multiple of 10.

Call AlazarSetCaptureClock() specifying EXTERNAL_CLOCK_10MHz_REF as the clock source and 500 MHz as the sample rate value, and a decimation of 1, 2, 4, or any multiple of 10 up to 100000. For example, the following code fragment shows how to generate a 125 MS/s sample rate (500 MHz / 4) from a 10 MHz external clock input:

```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  500000000, // U32 - sample rate Id or value
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  4 // U32 - decimation value
  );
```

ATS9870

In 10 MHz PLL external clock mode, the ATS9870 generates a 1 GHz sample clock from an external 10 MHz reference input. The 1 GS/s sample data can be decimated by a factor of 1, 2, 4, or any multiple of 10.

Call AlazarSetCaptureClock() specifying EXTERNAL_CLOCK_10MHz_REF as the clock source and 1 GHz as the sample rate value, and a decimation of 1, 2, 4, or any multiple of 10 up to 100000. For example, the following code fragment shows how to generate a 250 MS/s sample rate (1 GHz / 4) from a 10 MHz external clock input:

```
AlazarSetCaptureClock(
  handle, // HANDLE - board handle
  EXTERNAL_CLOCK_10MHz_REF, // U32 - clock source Id
  1000000000, // U32 - sample rate Id or value
  CLOCK_EDGE_RISING, // U32 - clock edge Id
  4 // U32 - decimation value
  );
```

Input control

AlazarTech digitizers have analog amplifier sections that process the signals input to its analog input connectors before they are sampled by its ADC converters. The gain, coupling, and termination of the amplifier sections should be configured to match the properties of the input signals.

Input range, coupling, and impedance

Call `AlazarInputControl()` to specify the desired input range, termination, and coupling of an input channel. The following code fragment configures input CH A for a range of ±800 mV, DC coupling, and 50Ω termination:

```
AlazarInputControl(
  boardHandle, // HANDLE -- board handle
  CHANNEL_A, // U8 -- input channel
  DC_COUPLING, // U32 -- input coupling id
  INPUT_RANGE_PM_800_MV, // U32 -- input range id
  IMPEDANCE_50_OHM // U32 -- input impedance id
  );
```

See `AlazarInputControl()` and the board reference manual for a list of input range, coupling, and impedance identifiers appropriate for the board.

Bandwidth filter

Some digitizers have a low pass filters that attenuate signals above about 20 MHz. By default, these filters are disabled. Call `AlazarSetBWLimit()` to enable or disable the bandwidth limit filter. The following code fragment enables the CH A bandwidth limit filter:

```
AlazarSetBWLimit (
  boardHandle, // HANDLE -- board handle
  CHANNEL_A, // U32 -- channel identifier
  1 // U32 -- 0 = disable, 1 = enable
  );
```

Amplifier bypass

Some digitizer models support “amplifier bypass” mode. In this mode, the analog signal supplied to an input connector is connected directly the ADC driver of that channel, bypassing its amplifier section. Amplifier bypass mode must be enabled in hardware either through DIP switches on the board, or as a factory option. Once enabled in hardware, the following code fragment shows how to configure this option in software:

```
AlazarInputControl(
  handle, // HANDLE -- board handle
  CHANNEL_A, // U8 -- input channel
  DC_COUPLING, // U32 - not used
  INPUT_RANGE_HI_FI, // U32 -- input range id
```

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```
  IMPEDANCE_50_OHM // U32 - not used
  );
```

Note that when amplifier bypass mode option is enabled for an input channel, the channel's full-scale input range is fixed. The following table lists the nominal full-scale input range values that may be used to convert sample code values to volts.

Model	Full scale input range
ATS460	± 525 mV
ATS660	± 550 mV
ATS9325/ATS9350	± 200 mV
ATS9351	± 400 mV
ATS9462	± 550 mV
ATS9850/ATS9870	± 256 mV

See your board's hardware reference manual for more information about using amplifier bypass.

Trigger control

AlazarTech digitizer boards have a flexible triggering system with two separate trigger engines that can be used independently, or combined together to generate trigger events.

Warning: As opposed to what earlier documentation mentionned, the only way to combine trigger events is with the *OR* operator.

AlazarSetTriggerOperation

Use the `AlazarSetTriggerOperation()` API function to configure each of the two trigger engines, and to specify how they should be used to make the board trigger:

```
RETURN_CODE
AlazarSetTriggerOperation (
  HANDLE handle,
  U32 TriggerOperation,
  U32 TriggerEngineId1,
  U32 SourceId1,
  U32 SlopeId1,
  U32 Level1,
  U32 TriggerEngineId2,
  U32 SourceId2,
  U32 SlopeId2,
  U32 Level2
  );
```

The following paragraphs describe each of the function's parameters, and provide examples showing how to use the function.

Trigger engine

The trigger engine identifier parameter specifies which of the two trigger engines you wish to configure. The parameter may have one of the following values:

TRIG_ENGINE_J Configure trigger engine J

TRIG_ENGINE_K Configure trigger engine K

Data source

The data source identifier parameter selects the where the specified trigger engine should get its data. Refer to the documentation of the `AlazarSetTriggerOperation()` function for a list of all possible values.

Trigger slope

The trigger slope identifier parameter selects whether rising or falling edges of the trigger source are detected as trigger events.

TRIGGER_SLOPE_POSITIVE The trigger engine detects a trigger event when sample values from the trigger source rise above a specified level.

TRIGGER_SLOPE_NEGATIVE The trigger engine detects a trigger event when sample values from the trigger source fall below a specified level.

Trigger level

The trigger level parameter sets the level that the trigger source must rise above, or fall below, for the selected trigger engine to become active. The trigger level is specified as an unsigned 8-bit code that represents a fraction of the full scale input range of the trigger source; 0 represents the negative full-scale input, 128 represents a 0 volt input, and 255 represents the positive full-scale input. For example, if the trigger source is CH A, and the CH A input range is ± 800 mV, then 0 represents a –800 mV trigger level, 128 represents a 0 V trigger level, and 255 represents +800 mV trigger level.

In general, the trigger level value is given by:

```
TriggerLevelCode = 128 + 127 * TriggerLevelVolts / InputRangeVolts.
```

The following table gives examples of how trigger level codes map to trigger levels in volts according to the full-scale input range of the trigger source.

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Code	Fraction of input range	Level with ±1 V range	Level with ±5 V range
0	-100%	-1V	-5V
64	-50%	-500 mV	-2.5 V
96	-25%	-250 mV	-1.25 V
128	0%	0 V	0 V
160	+25 %	250 mV	1.25 V
192	+50%	+500 mV	+2.5 V
255	+100%	+1V	+5V

Trigger operation

Finally, the trigger operation identifier specifies how the trigger events detected by the trigger engines are combined to make the board trigger. Possible values are:

TRIG_ENGINE_OP_J The board triggers when trigger engine J detects a trigger event. Events detected by engine K are ignored.

TRIG_ENGINE_OP_K The board triggers when trigger engine K detects a trigger event. Events detected by engine J are ignored.

TRIG_ENGINE_OP_J_OR_K The board triggers when a trigger event is detected by any of trigger engines J and K.

AlazarSetTriggerOperation examples

The following code fragment configures a board to trigger when the signal connected to CH A rises above 0V. This example only uses trigger engine J:

```
AlazarSetTriggerOperation(
  handle, // HANDLE -- board handle
  TRIG_ENGINE_OP_J, // U32 -- trigger operation
  TRIG_ENGINE_J, // U32 -- trigger engine id
  TRIG_CHAN_A, // U32 -- trigger source id
  TRIGGER_SLOPE_POSITIVE, // U32 -- trigger slope id
  128, // U32 -- trigger level (128 = 0V)
  TRIG_ENGINE_K, // U32 -- trigger engine id
  TRIG_DISABLE, // U32 -- trigger source id for engine K
  TRIGGER_SLOPE_POSITIVE, // U32 -- trigger slope id
  128 // U32 -- trigger level (0  255)
  );
```

The following code fragment configures a board to trigger when the signal connected to CH B rises above 500 mV, or falls below -200 mV, if CH B's input range is ±1V. This example uses both trigger engine J and K:

```
double inputRange_volts = 1.; // ±1V range
double TriggerLevelJ_volts = .5; // +500 mV trigger level
U32 triggerLevelJ = (U32)(128 + 127 * triggerLevelJ_volts / inputRange_volts);
double triggerLevelK_volts = -.2; // -200 mV trigger level
U32 triggerLevelK = (U32)(128 + 127 * triggerLevelK_volts / inputRange_volts);
```

```
AlazarSetTriggerOperation(
  handle, // HANDLE -- board handle
  TRIG_ENGINE_OP_J_OR_K, // U32 -- trigger operation
  TRIG_ENGINE_J, // U32 -- trigger engine id
  TRIG_CHAN_B, // U32 -- trigger source id
  TRIGGER_SLOPE_POSITIVE, // U32 -- trigger slope id
  triggerLevelJ, // U32 -- trigger level from 0 to 255
  TRIG_ENGINE_K, // U32 -- trigger engine id
  TRIG_DISABLE, // U32 -- trigger source id for engine K
  TRIGGER_SLOPE_POSITIVE, // U32 -- trigger slope id
  triggerLevelK, // U32 -- trigger level from 0 to 255
  );
```

External trigger

AlazarTech digitizer boards can trigger on a signal connected to its TRIG IN connector. To use an external trigger input:

- Call `AlazarSetTriggerOperation()` with `TRIG_EXTERNAL` as the trigger source identifier of at least one of the trigger engines; and
- Call `AlazarSetExternalTrigger()` to select the range and coupling of the external trigger input.

The following code fragment configures a board to trigger when the signal connected to the TRIG IN falls below +2 V, assuming the signal's range is less than ± 5V with DC coupling:

```
// Calculate the trigger level code from the level and range
double triggerLevel_volts = 2.; // trigger level
double triggerRange_volts = 5.; // input range
U32 triggerLevel_code =
(U32)(128 + 127 * triggerLevel_volts / triggerRange_volts);

// Configure trigger engine J to generate a trigger event
// on the falling edge of an external trigger signal.
AlazarSetTriggerOperation(
  handle, // HANDLE -- board handle
  TRIG_ENGINE_OP_J, // U32 -- trigger operation
  TRIG_ENGINE_J, // U32 -- trigger engine id
  TRIG_EXTERNAL, // U32 -- trigger source id
  TRIGGER_SLOPE_NEGATIVE, // U32 -- trigger slope id
  triggerLevel, // U32 -- trigger level (0  255)
  TRIG_ENGINE_K, // U32 -- trigger engine id
  TRIG_DISABLE, // U32 -- trigger source id for engine K
  TRIGGER_SLOPE_POSITIVE, // U32 -- trigger slope id
  128 // U32 -- trigger level (0  255)
  );

// Configure the external trigger input to +/-5V range,
// with DC coupling
AlazarSetExternalTrigger(
  handle, // HANDLE -- board handle
```

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```
  DC_COUPLING, // U32 -- coupling id
  ETR_5V // U32 -- external range id
  );
```

Trigger timeout

AlazarTech digitizer boards can be configured to automatically trigger when the board is waiting for a trigger event, but no trigger events arrive after a specified time interval. This behavior is similar to the "automatic" trigger mode of oscilloscopes, and may be useful to capture waveforms when trigger conditions are unknown. Call `AlazarSetTriggerTimeOut()` to specify the amount of time that a board should wait for a hardware trigger event before automatically generating a software trigger event and, as a result, acquiring one record. The timeout value is expressed in 10 μs units, where 0 means disable the timeout counter and wait forever for a trigger event.

Note: The trigger timeout value should be set to zero once stable trigger parameters have been found. Otherwise, a board may generate unexpected trigger events if the trigger timeout interval expires before a hardware trigger event occurs.

The following code fragment configures a board to automatically trigger and acquire one record if it does not receive a trigger event after 1 ms:

```
double timeout_sec = 1.e-3; // 1 ms
U32 timeout_ticks = (U32)(timeout_sec / 10.e-6 + 0.5);
AlazarSetTriggerTimeOut(
  boardHandle, // HANDLE -- board handle
  timeout_ticks // U32  timeout_sec / 10.e-6 (0 = infinite)
  );
```

The following code fragment configures a board to wait forever for trigger events:

```
AlazarSetTriggerTimeOut(
  boardHandle, // HANDLE -- board handle
  0 // U32 -- timeout\_sec / 10.e-6 (0 = infinite)
  );
```

Trigger delay

An AlazarTech digitizer board can be configured to wait for a specified amount of time after it receives a trigger event before capturing a record for the trigger. Call `AlazarSetTriggerDelay()` to specify a time, in sample clock periods, to wait after receiving a trigger event for a record before capturing samples for that record. The following code fragment shows how to set a trigger delay of 1 ms, given a sample rate of 100 MS/s:

```
double triggerDelay_sec = 1.e-3; // 1 ms
double samplesPerSec = 100.e6; // 100 MS/s
U32 triggerDelay_samples =
```

```
(U32)(triggerDelay_sec * samplesPerSec + 0.5);
AlazarSetTriggerDelay(
  boardHandle, // HANDLE -- board handle
  triggerDelay_samples // U32 -- trigger delay in samples
  );
```

AUX I/O

AlazarTech digitizer boards with an AUX I/O connector can be configured to supply a 5V TTL-level output signal, or to receive a TTL-level input signal on this connector. Use `AlazarConfigureAuxIO()` to configure the function of the AUX I/O connector.

The ATS9440 has two AUX I/O connectors: AUX I/O 1 and AUX I/O 2. AUX I/O 1 is configured by firmware as a trigger output signal, while AUX I/O 2 is configured by software using `AlazarConfigureAuxIO()`. A custom FPGA is required to change the operation of AUX I/O 1.

The ATS9625 and ATS9626 have two AUX I/O connectors: AUX1 and AUX2. AUX1 is configured by by software using `AlazarConfigureAuxIO()`, while AUX2 is configured by the main FPGA as a trigger output signal by default. AUX2 can be controlled by its user-programmable FPGA as desired by the FPGA designer.

Trigger output

The AUX I/O connector can be configured to supply a trigger output signal, where the edge of the trigger output signal is synchronized with the edge of the sample clock. Note that this is the default power-on mode for the AUX I/O connector. The following code fragment configures the AUX I/O connector as a trigger output signal:

```
AlazarConfigureAuxIO(
  handle, // HANDLE -- board handle
  AUX_OUT_TRIGGER, // U32 -- mode
  0 // U32 -- parameter
  );
```

Pacer output

The AUX I/O connector can be configured to output the sample clock divided by a programmable value. This option may be used to generate a clock signal synchronized with the sample clock of the digitizer board. The following code fragment generates a 10 MHz signal on an AUX I/O connector, given a sample rate of 180 MS/s:

```
AlazarConfigureAuxIO(
  handle, // HANDLE -- board handle
  AUX_OUT_PACER, // U32 -- mode
  18 // U32 - sample clock divider
  );
```

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Note that the sample rate divider value must be greater than 2, and that the signal output may be limited by the bandwidth of the output's TTL drivers.

Digital output

The AUX I/O connector can be configured to output a TTL high or low signal. This mode allows a programmer to use the AUX I/O connector as a general purpose digital output. The following code fragment configures the AUX I/O connector as a digital output:

```
AlazarConfigureAuxIO(
  handle, // HANDLE -- board handle
  AUX_OUT_SERIAL_DATA, // U32 -- mode
  0 // U32 - 0 = low, 1 = high
  );
```

Trigger enable input

The AUX I/O connector can be configured as an AutoDMA trigger enable input signal. When enabled, a board will:

- Wait for a rising or falling edge on the AUX I/O.
- Wait for the number of trigger events necessary to capture the number of "records per buffer" in one AutoDMA segment specified at the start of the acquisition.
- Repeat.

The following code fragment configures the AUX I/O connector to acquire "records per buffer" records after it receives the rising edge of a TTL pulse connected on the AUX I/O connector:

```
AlazarConfigureAuxIO(
  handle, // HANDLE -- board handle
  AUX_IN_TRIGGER_ENABLE, // U32 -- mode
  TRIGGER_SLOPE_POSITIVE // U32 -- parameter
  );
```

See *Scanning Applications* for more information.

Digital input

The AUX I/O connector can be configured to read the TTL level of a signal input to the AUX connector. This mode allows a programmer to use the AUX I/O connector as a general purpose digital input. The following code fragment configures the AUX I/O connector as a digital input:

```
AlazarConfigureAuxIO(
  handle, // HANDLE -- board handle
  AUX_IN_AUXILIARY, // U32 -- mode
  0 // U32 - not used
  );
```

Once configured as a serial input, the following code fragment reads the AUX input level:

```
long level;
AlazarGetParameter(
  handle, // HANDLE -- board handle
  0, // U8 -- channel
  GET_AUX_INPUT_LEVEL, // U32 -- parameter
  &level // long* - 0 = low, 1 = high
  );
```

Data packing

By default, all the boards that have more than 8-bit per sample sampling transfer data to the host computer with 2 bytes (16 bit) per sample. This behavior can be changed on some boards by packing the data, either to 8- or 12-bits per sample. This is done by calling the AlazarSetParameter function with the PACK_MODE parameter and a packing option (either PACK_DEFAULT, PACK_8_BITS_PER_SAMPLE or PACK_12_BITS_PER_SAMPLE). The parameter must be set before calling AlazarBeforeAsyncRead.

For a list of boards that implement 8-bit packing, 12-bit packing and both; please refer to *Table 9 – Miscellaneous Features Support*.

Dual edge sampling

Some AlazarTech digitizers are capable of dual edge sampling (DES), meaning that sample data is acquired both at the rising and falling edge of the clock signal. This mode can apply both to internal and external clocks. For example, ATS9373 is capable of 2 GS/s sampling in non-DES mode, and 4 GS/s in DES mode. When using the internal clock, DES sampling is activated automatically. Data must be acquired from channel A only. To use DES sampling in external clock mode, one must call AlazarSetParameter as follows *before* configuring the board:

```
AlazarSetParameterUL(
  handle, // HANDLE -- board handle
  channelMask, // U8 -- channel to acquire
  SET_ADC_MODE,
  ADC_MODE_DES
  );
```

Programs that wish to use DES-capable digitizers in non-DES mode (i.e. ATS9373 at sampling frequencies at or below 2GS/s) do not need to be modified.

NPT footers

Footers can be included to the data and contain additional information about the acquisition of each record. The footers include a timestamp, the record number in the current acquisition, a frame count and the state of the AUX I/O signal at the time of the acquisition. As the name implies, this option is only available in NPT acquisition mode.

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Depending if on-FPGA FFT is used or not, the function to retrive the NPT footers and their position in memory is different. If FFT is not enabled, NPT footers will *replace* the last 16 bytes of a record, leading to a loss of a few data points. These NPT footers are labeled Time-Domain to highlighting the fact that FFT is not used. When one channel is enabled, the last 8 samples of the data will be removed. When two channels are enabled, only one footer will be appended per record and will take the place of the last 4 samples from each channel.

When using on-FPGA FFT, a 128-byte word will be appended to each record. The last 16 bytes of this 128-byte word contain the footer.

For convenience, a structure named **:cpp:struct:'NPTFooter'** should be used. Here is how to enable and obtain the NPT footers:

- Connect the start of frame signal to the AUX I/O connector.
- Append the flag `ADMA_ENABLE_RECORD_FOOTERS` to the options passed to `AlazarBeforeAsyncRead()` by using a binary OR (|). Make sure the acquisition mode is set to `ADMA_NPT` and FFT processing is enabled if applicable.
- Call `AlazarConfigureAuxIO()` specifying `AUX_IN_AUXILIARY` as the mode with *0* as parameter.
- Create an array that will contain the NPT footers. This array needs to be contiguous in memory and can thus be a standard C array or a *std::vector* with preallocated size.
- Call `AlazarExtractTimeDomainNPTFooters()` or `AlazarExtractFFTNPTFooters()` to retrieve the NPT footers for each buffer and store them in the array. The *recordSize_bytes* parameter needs to take into account the number of active channels.
- Browse the array to see the frame associated with each record and count the number of records in each frame if needed.

See the API reference documentation for details about the specific parameters to use with each function.

Acquiring data

AlazarTech digitizers may be configured to acquire in one of the following modes:

- *Single port acquisition* mode acquires data to on-board memory and then, after the acquisition is complete, transfers data from on-board memory to application buffers.
- *Dual port AutoDMA acquisition* mode acquires to on-board memory while, at the same time, transferring data from on-board memory to application buffers.

Single port acquisition

The single-port acquisition API allows an application to capture records to on-board memory – one per trigger event – and transfer records from on-board to host memory. Data acquisition and data transfer are made serially, so trigger events may be missed if they occur during data transfers. The single port acquisition API may be used if:

- A board has single-port or dual-port on-board memory.

- An application can miss trigger events that occur while it is transferring data from on-board to host memory.

The singe port acquisition API must be used if:

- A board does not have dual-port or FIFO on-board memory.
- An application acquires data at an average rate that is greater than maximum transfer rate of the board's PCI or PCIe host bus interface.

Ultrasonic testing, OCT, radar, imaging and similar applications should not use the single-port acquisition API; rather, they should use the dual-port acquisition API described in section 2.4.2 below.

Acquiring to on-board memory

All channels mode

By default, AlazarTech digitizer boards share on-board memory equally between both of a board's input channels. A single-port acquisition in dual-channel mode captures samples from both input channels simultaneously to on-board memory and, after the acquisition is complete, allows samples from either input channel to be transferred from on-board memory to an application buffer. To program a board acquire to on-board memory in dual-channel mode:

1. Call `AlazarSetRecordSize()` to set the number of samples per record, where a record may contain samples before and after its trigger event.
2. Call `AlazarSetRecordCount()` to set the number records per acquisition – the board captures one record per trigger event.
3. Call `AlazarStartCapture()` to arm the board to wait for trigger events.
4. Call `AlazarBusy()` in a loop to poll until the board has received all trigger events in the acquisition, and has captured all records to on-board memory.
5. Call `AlazarRead()`, `AlazarReadEx()`, or `AlazarHyperDisp()` to transfer records from on-board memory to host memory.
6. Repeat from step 3, if necessary.

The following code fragment acquires to on board memory with on-board memory shared between both input channels:

```
// 1. Set record size
AlazarSetRecordSize (
  boardHandle, // HANDLE -- board handle
  preTriggerSamples, // U32 -- pre-trigger samples
  postTriggerSamples // U32 -- post-trigger samples
  );

// 2. Set record count
AlazarSetRecordCount(
  boardHandle, // HANDLE -- board handle
```

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```
  recordsPerCapture // U32 -- records per acquisition
  );

// 3. Arm the board to wait for trigger events
AlazarStartCapture(boardHandle);

// 4. Wait for the board to receive all trigger events and capture all
//    records to on-board memory

while (AlazarBusy (boardHandle))
{
  // The acquisition is in progress
}

// 5. The acquisition is complete. Call AlazarRead or AlazarHyperDisp to
//    transfer records from on-board memory to your buffer.
```

Single channel mode

ATS9325, ATS9350, ATS9351, ATS9440, ATS9625, ATS9626, ATS9850, and ATS9870 and digitizer boards can be configured to dedicate all on-board memory to one of a board's input channels. A single-port acquisition in single-channel mode only captures samples from the specified channel to on-board memory and, after the acquisition is complete, only allows samples from the specified channel to be transferred from on-board memory to an application buffer.

To program a board acquire to on-board memory in single-channel mode:

1. Call `AlazarSetRecordSize()` to set the number of samples per record, where a record may contain samples before and after its trigger event.
2. Call `AlazarSetRecordCount()` to set the number records per acquisition – the board captures one record per trigger event.
3. Call `AlazarSetParameter()` with the parameter `SET_SINGLE_CHANNEL_MODE`, and specify the channel to use all memory.
4. Call `AlazarStartCapture()` to arm the board to wait for trigger events.
5. Call `AlazarBusy()` in a loop to poll until the board has received all trigger events in the acquisition, and has captured all records to on-board memory.
6. Call `AlazarRead()`, `AlazarReadEx()`, or `AlazarHyperDisp()` to transfer records from on-board memory to host memory.
7. Repeat from step 3, if necessary.

The following code fragment acquires to on-board memory from CH A in single channel mode:

```
// 1. Set record size
AlazarSetRecordSize (
  boardHandle, // HANDLE -- board handle
  preTriggerSamples, // U32 -- pre-trigger samples
  postTriggerSamples // U32 -- post-trigger samples
```

```
  );

// 2. Set record count
AlazarSetRecordCount(
  boardHandle, // HANDLE -- board handle
  recordsPerCapture // U32 -- records per acquisition
  );

// 3. Enable single channel mode
AlazarSetParameter(
  boardHandle, // HANDLE -- board handle
  0, // U8 -- channel Id (not used)
  SET_SINGLE_CHANNEL_MODE, // U32 -- parameter
  CHANNEL_A // long  CHANNEL_A or CHANNEL_B
  );

// 4. Arm the board to wait for trigger events
AlazarStartCapture(boardHandle);

// 5. Wait for the board to receive all trigger events
//    and capture all records to on-board memory
while (AlazarBusy (boardHandle))
{
  // The acquisition is in progress
}

// 6. The acquisition is complete. Call AlazarRead or
//    AlazarHyperDisp to transfer records from on-board memory
//    to your buffer.
```

Note: A call to `AlazarSetParameter()` must be made before each call to `AlazarStartCapture()`.

If the of number of samples per record specified in `AlazarSetRecordSize()` is greater than the maximum number of samples per channel in dual-channel mode, but is less than the maximum number of samples per record in single-channel mode, and `AlazarSetParameter()` is not called before calling `AlazarStartCapture()`, then `AlazarStartCapture()` will fail with error `ApiNotSupportedInDualChannelMode`.

Using AlazarRead

Use `AlazarRead()` to transfer samples from records acquired to on-board memory to a buffer in host memory.

Transferring full records

The following code fragment transfers a full CH A record from on-board memory to a buffer in host memory:

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```
// Allocate a buffer to hold one record.
// Note that the buffer must be at least 16 samples
// larger than the number of samples per record.
U32 allocBytes = bytesPerSample * (samplesPerRecord + 16);
void* buffer = malloc(allocBytes);

// Transfer a CHA record into our buffer
AlazarRead (
  boardHandle, // HANDLE -- board handle
  CHANNEL_A, // U32 -- channel Id
  buffer, // void* -- buffer
  bytesPerSample, // int -- bytes per sample
  (long) record, // long -- record (1 indexed)
  -((long)preTriggerSamples), // long -- trigger offset
  samplesPerRecord // U32 -- samples to transfer
  );
```

See "%ATS_SDK_DIR%\Samples\SinglePort\AR" for a complete sample program that demonstrates how to use `AlazarRead()` to read full records.

Transferring partial records

`AlazarRead()` can transfer a segment of a record from on-board memory to a buffer in host memory. This may be useful if:

- The number of bytes in a full record in on-board memory exceeds the buffer size in bytes that an application can allocate in host memory.
- An application wishes to reduce the time required for data transfer when it acquires relatively long records to on-board memory, but is only interested in a relatively small part of the record.

Use the `transferOffset` parameter in the call to `AlazarRead()` to specify the offset, in samples from the trigger position in the record, of the first sample to transfer from on-board memory to the application buffer. And use the `transferLength` parameter to specify the number of samples to transfer from on-board memory to the application buffer, where this number of samples may be less than the number of samples per record. The following code fragment divides a record into segments, and transfers the segments from on-board to host memory:

```
// Allocate a buffer to hold one record segment.
// Note that the buffer must be at least 16 samples
// larger than the number of samples per buffer.
U32 allocBytes = bytesPerSample * (samplesPerBuffer + 16);
void* buffer = malloc(allocBytes);

// Transfer a record in segments from on-board memory
U32 samplesToRead = samplesPerRecord;
long triggerOffset_samples = -(long)preTriggerSamples;
while (samplesToRead > 0) {
  // Transfer a record segment from on-board memory
  U32 samplesThisRead;
  if (samplesToRead > samplesPerBuffer)
```

```
    samplesThisRead = samplesPerBuffer;
  else
    samplesThisRead = samplesToRead;
  AlazarRead (
    boardHandle, // HANDLE -- board handle
    CHANNEL_A, // U32 -- channel Id
    buffer, // void* -- buffer
    bytesPerSample, // int -- bytes per sample
    (long) record, // long -- record (1 indexed)
    triggerOffset_samples, // long -- trigger offset
    samplesThisRead // U32 -- samples to transfer
    );

  // Process the record segment here
  WriteSamplesToFile(buffer, samplesThisRead);

  // Point to next record segment in on-board memory
  triggerOffset_samples += samplesThisRead;

  // Decrement number of samples left to read
  samplesToRead -= samplesThisRead;
}
```

See "%ATS_SDK_DIR%\Samples\SinglePort\AR_Segments" for a complete sample program that demonstrates how to read records in segments.

Using AlazarReadEx

`AlazarRead()` can transfer samples from records acquired to on-board memory that contain up to 2,147,483,647 samples. If a record contains 2,147,483,648 or more samples, use `AlazarReadEx()` rather than `AlazarRead()`. `AlazarReadEx()` uses signed 64-bit transfer offsets, while `AlazarRead()` uses signed 32-bit transfer offsets. Otherwise, `AlazarReadEx()` and `AlazarRead()` are identical.

Using AlazarHyperDisp

HyperDisp technology enables the FPGA on an AlazarTech digitizer board to process sample data. The FPGA divides a record in on-board memory into intervals, finds the minimum and maximum sample values during each interval, and transfers an array of minimum and maximum value pairs to host memory. This allows the acquisition of relatively long records to on-board memory, but the transfer of relatively short processed records across the PCI/PCIe bus to host memory.

For example, an ATS860-256M would require over 2 seconds per channel to transfer 256,000,000 samples across the PCI bus. However, with HyperDisp enabled the ATS860 would require a fraction of a second to calculate HyperDisp data, and transfer a few kilobytes of processed data across the PCI bus. If an application was searching these records for glitches, it may save a considerable amount of time by searching HyperDisp data for the glitches and, if a glitch were found, transfer the raw sample data from the interval from on-board memory to host memory.

Use `AlazarHyperDisp()` to enable a board to process records in on-board memory, and transfer

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processed records to host memory. The following code fragment enables an ATS860-256M to process a record in on-board memory containing 250,000,000 samples into an array of 100 HyperDisp points, where each point contains the minimum and maximum sample values over an interval of 2,500,000 samples in the record:

```
// Specify number of samples per record
U32 preTriggerSamples = 125000000;
U32 postTriggerSamples = 125000000;
U32 samplesPerRecord = preTriggerSamples + postTriggerSamples;
U32 recordsPerCapture = 1;

// Acquire to on-board memory (omitted)
// Specify the number of HyperDisp points
U32 pointsPerRecord = 100;

// Allocate a buffer to store the HyperDisp data
U32 bytesPerSample = 1; // ATS860 constant
U32 samplesPerPoint = 2; // HyperDisp constant
U32 bytesPerBuffer = bytesPerSample * samplesPerPoint * pointsPerRecord;
U8 *buffer = (U8*) malloc(bytesPerBuffer);

// Enable ATS860 FPGA to process the 250M sample record
// in on-board memory into an array of 100 HyperDisp points,
// and transfer the HyperDisp points into our buffer
U32 error;

AlazarHyperDisp (
  boardHandle, // HANDLE -- board handle
  NULL, // void* -- reserved
  samplesPerRecord, // U32 -- BufferSize
  (U8*) buffer, // U8* -- ViewBuffer
  bytesPerBuffer, // U32 -- ViewBufferSize
  pointsPerRecord, // U32 -- NumOfPixels
  1, // U32 -- Option (1 = HyperDisp)
  CHANNEL_A, // U32 -- ChannelSelect
  1, // U32 -- record (1 indexed)
  -(long)preTriggerSamples, // long -- TransferOffset
  &error // U32* -- error
  );
```

See "%ATS_SDK_DIR%\Samples\SinglePort\HD" for a complete sample program that demonstrates how to use `AlazarHyperDisp()`.

Record timestamps

AlazarTech digitizer boards include a 40-bit counter clocked by the sample clock source scaled by a board specific divider. When a board receives a trigger event to capture a record to on-board memory, it latches and saves the value of this counter. The counter value gives the time, relative to when the counter was reset, when the trigger event for the record occurred.

By default, this counter is reset to zero at the start of each acquisition. Use `AlazarResetTimeStamp()` to control when the record timestamp counter is reset.

Use AlazarGetTriggerAddress() to retrieve the timestamp, in timestamp clock ticks, of a record acquired to on-board memory. This function does not convert the timestamp value to seconds. The following code fragment gets the record timestamp of a record acquired to on-board memory, and converts the timestamp value from clocks ticks to seconds:

```
// Read the record timestamp
U32 triggerAddress;
U32 timestampHigh;
U32 timestampLow;

AlazarGetTriggerAddress (
boardHandle, // HANDLE -- board handle
record, // U32 -- record number (1-indexed)
&triggerAddress, // U32* -- trigger address
&timestampHigh, // U32* -- timestamp high part
&timestampLow // U32* -- timestamp low part
);

// Convert the record timestamp from counts to seconds
__int64 timeStamp_cnt;
timeStamp_cnt = ((__int64) timestampHigh) << 8;
timeStamp_cnt |= timestampLow & 0x0ff;
double samplesPerTimestampCount = 2; // board specific constant
double samplesPerSec = 50.e6; // sample rate
double timeStamp_sec = (double) samplesPerTimestampCount *
                       timeStamp_cnt / samplesPerSec;
```

Call AlazarGetParameter() with the GET_SAMPLES_PER_TIMESTAMP_CLOCK parameter to obtain the board specific "samples per timestamp count" value. See *Samples per record alignment requirements* for a list of these values. See "%ATS_SDK_DIR%\Samples\SinglePort\AR_Timestamps" for a complete sample program that demonstrates how to retrieve record timestamps and convert them to seconds.

Master-slave applications

If the single-port API is used to acquire from master-slave board system, only the master board in the board system should receive calls to the following API functions: AlazarStartCapture(), AlazarAbortCapture(), AlazarBusy(), AlazarTriggered() and AlazarForceTrigger(). See "%ATS_SDK_DIR%\Samples\SinglePort\AR_MasterSlave" for a sample program that demonstrates how to acquire from a master-slave system.

Dual port AutoDMA acquisition

AutoDMA allows a board to capture sample data to on-board dual-port memory while – at the same time – transferring sample data from on-board dual-port memory to a buffer in host memory. Data acquisition and data transfer are done in parallel, so any trigger events that occur while the board is transferring data will not be missed.

AutoDMA may be used if:

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- A board has dual-port or FIFO on-board memory.
- An application acquires at an average rate, in MB/s, that is less than maximum transfer rate of your board's PCI or PCIe host bus interface.

AutoDMA must be used if:

- A board has FIFO on-board memory.
- An application cannot miss trigger events that occur while it transfers data to host memory, or re-arms for another acquisition.
- An application acquires more sample points or records than can be stored in on-board memory.

Applications such as ultrasonic testing, OCT, radar, and imaging should use AutoDMA. An AutoDMA acquisition is divided into segments. AutoDMA hardware on a board transfers sample data, one segment at a time, from on-board memory to a buffer in host memory. There may be an unlimited number of segments in an AutoDMA acquisition, so a board can be armed to make an acquisition of infinite duration. There are four AutoDMA operating modes:

Traditional AutoDMA This mode acquires multiple records, one per trigger event. Each record may contain samples before and after its trigger event. Each buffer contains one or more records. A record header may optionally precede each record. Supports low trigger repeat rates.

NPT AutoDMA Acquires multiple records, one per trigger event. Some boards support a very limited number of pre-trigger samples. Otherwise, only post-trigger samples are possible. Each buffer contains one or more record. Supports high trigger repetition rates.

Triggered streaming AutoDMA Acquires a single, gapless record spanning one or more DMA buffers. Each DMA buffer then contains only a segment of the record. This mode waits for a trigger event before acquiring the record.

Continuous streaming AutoDMA Acquires a single, gapless record spanning one or more DMA buffers. Each DMA buffer then contains only a segment of the record. This mode does not wait for a trigger event before acquiring the record.

To make an AutoDMA acquisition, an application must:

- Specify the AutoDMA mode, samples per record, records per buffer, and records per acquisition.
- Arm the board to start the acquisition.
- Wait for an AutoDMA buffer to be filled, process the buffer, and repeat until the acquisition is complete.

Traditional AutoDMA

Use traditional mode to acquire multiple records – one per trigger event – with sample points after, and optionally before, the trigger event in each record. A record header may optionally precede each record in the AutoDMA buffer. The programmer specifies the number of samples per record, records per buffer, and buffers in the acquisition. Traditional AutoDMA supports low trigger

repeat rates. For high trigger repeat rates, use NPT AutoDMA mode. Digitizers with four analog input channels do not support 3-channel operation, and require sample interleave to allow for high transfer rates from on-board memory.

Each buffer is organized in memory as follows if a board has on-board memory. Rxy represents a contiguous array of samples from record x of channel y.

Enabled channels	Buffer organization
CH A	R1A, R2A, R3A, . . . RnA
CH B	R1B, R2B, R3B . . . RnB
CH A and CH B	R1A, R1B, R2A, R2B, R3A, R3B . . . RnA, RnB
CH C	R1C, R2C, R3C . . . RnC
CH A and CH C	R1A, R1C, R2A, R2C, R3A, R3C . . . RnA, RnC
CH B and CH C	R1B, R1C, R2B, R2C, R3B, R3C . . . RnB, RnC
CH D	R1D, R2D, R3D . . . RnD
CH A and CH D	R1A, R1D, R2A, R2D, R3A, R3D . . . RnA, RnD
CH B and CH D	R1B, R1D, R2B, R2D, R3B, R3D . . . RnB, RnD
CH C and CH D	R1C, R1D, R2C, R2D, R3C, R3D . . . RnC, RnD
CH A, CH B, CH C and CH D	R1A, R1B, R1C, R1D, R2A, R2B, R2C, R2D, R3A, R3B, R3C, R3D . . . RnA, RnB, RnC, RnD

Each buffer is organized in memory as follows if a board does not have on-board memory, or if sample interleave is enabled. Rxy represents a contiguous array of samples from record x of channel y, Rx[uv] represents interleaved samples from record x of channels u and v, and Rx[uvyz] represents interleaved samples from channels u, v, y, and z.

Enabled channels	Buffer organization
CH A	R1A, R2A, R3A, . . . RnA
CH B	R1B, R2B, R3B . . . RnB
CH A and CH B	R1[ABAB. . .], R2[ABAB. . .], . . . Rn[ABAB. . .]
CH C	R1C, R2C, R3C . . . RnC
CH A and CH C	R1[ACAC. . .], R2[ACAC. . .], . . . Rn[ACAC. . .]
CH B and CH C	R1[BCBC. . .], R2[BCBC. . .], . . . Rn[BCBC. . .]
CH D	R1D R2D, R3D . . . RnD
CH A and CH D	R1[ADAD. . .], R2[ADAD. . .], . . . Rn[ADAD. . .]
CH B and CH D	R1[BDBD. . .], R2[BDBD. . .], . . . Rn[BDBD. . .]
CH C and CH D	R1[CDCD. . .], R2[CDCD. . .], . . . Rn[CDCD. . .]
CH A, CH B, CH C and CH C	R1[ABCDABDC . . .], R2[ABDCABDC . . .], . . . Rn[ABDCABDC. . .]

See “%ATS_SDK_DIR%\Samples\DualPort\TR” for a sample program that demonstrates how to make an AutoDMA acquisition in Traditional mode.

If record headers are enabled, then a 16-byte record header will precede each record in an AutoDMA buffer. The record header contains a record timestamp, as well as acquisition metadata. See *Record headers and timestamps* below for a discussion of AutoDMA record headers.

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NPT AutoDMA

Use NPT mode to acquire multiple records – one per trigger event – with no sample points before the trigger event in each record, and with no record headers. The programmer specifies the number of samples per record, records per buffer, and buffers in the acquisition. Note that NPT mode is highly optimized, and supports higher trigger repeats rate than possible in Traditional mode. Digitizers with four analog input channels do not support 3-channel operation, and require sample interleave to allow for high transfer rates from on-board memory.

Each buffer is organized in memory as follows if a board has on-board memory. Rxy represents a contiguous array of samples from record x of channel y.

Enabled channels	Buffer organization
CH A	R1A, R2A, R3A, . . . RnA
CH B	R1B, R2B, R3B . . . RnB
CH A and CH B	R1A, R2A, R3A . . . RnA, R1B, R2B, R3B . . . RnB
CH C	R1C, R2C, R3C, . . . RnC
CH A and CH B	R1A, R2A, R3A . . . RnA, R1B, R2B, R3B . . . RnB
CH B and CH C	R1B, R2B, R3B . . . RnB, R1C, R2C, R3C . . . RnC
CH D	R1D, R2D, R3D, . . . RnD
CH A and CH D	R1A, R2A, R3A . . . RnA, R1D, R2D, R3D . . . RnD
CH B and CH D	R1B, R2B, R3B . . . RnB, R1D, R2D, R3D . . . RnD
CH C and CH D	R1C, R2C, R3C . . . RnC, R1D, R2D, R3D . . . RnD
CH A, CH B, CH C, and CH D	R1A, R2A, R3A . . . RnA, R1B, R2B, R3B . . . RnB, R1C, R2C, R3C . . . RnC, R1D, R2D, R3D . . . RnD

Each buffer is organized in memory as follows if a board does not have on-board memory, or if sample interleave is enabled. Rxy represents a contiguous array of samples from record x of channel y, Rx[uv] represents interleaved samples from record x of channels u and v, and Rx[uvyz] represents interleaved samples from record x of channels u, v, y, and z.

Enabled channels	Buffer organization
CH A	R1A, R2A, R3A, . . . RnA
CH B	R1B, R2B, R3B . . . RnB
CH A and CH B	R1[ABAB. . .], R2[ABAB. . .], . . . Rn[ABAB. . .]
CH C	R1C, R2C, R3C . . . RnC
CH A and CH C	R1[ACAC. . .], R2[ACAC. . .], . . . Rn[ACAC. . .]
CH B and CH C	R1[BCBC. . .], R2[BCBC. . .], . . . Rn[BCBC. . .]
CH D	R1D R2D, R3D . . . RnD
CH A and CH D	R1[ADAD. . .], R2[ADAD. . .], . . . Rn[ADAD. . .]
CH B and CH D	R1[BDBD. . .], R2[BDBD. . .], . . . Rn[BDBD. . .]
CH C and CH D	R1[CDCD. . .], R2[CDCD. . .], . . . Rn[CDCD. . .]
CH A, CH B, CH C and CH D	R1[ABCDABCD . . .], R2[ABCDABCD . . .], . . . Rn[ABCDABCD. . .]

See “%ATS_SDK_DIR%\Samples\DualPort\NPT” for a sample program that demonstrates how to make an AutoDMA acquisition in NPT mode.

Continuous streaming AutoDMA

Use continuous streaming mode to acquire a single, gapless record that spans multiple buffers without waiting for a trigger event to start the acquisition. The programmer specifies the number of samples per buffer, and buffers per acquisition. Each buffer is organized as follows if a board has on-board memory. R1x represents a contiguous array of samples from channel x.

Enabled channels	Buffer organization
CH A	R1A
CH B	R1B
CH A and CH B	R1A, R1B
CH C	R1C
CH A and CH C	R1A, R1C
CH B and CH C	R1B, R1C
CH D	R1D
CH A and CH D	R1A, R1D
CH B and CH D	R1B, R1D
CH C and CH D	R1C, R1D
CH A, CH B, CH C and CH D	R1A, R1B, R1C, R1D

Each buffer is organized as follows if a board does not have on-board memory, or if sample interleave is enabled. R1x represents a contiguous array of samples from channel x, R1[uv] represents samples interleaved from channels u and v, and R1[uvyz] represents samples interleaved from channels u, v, y, and z.

Enabled channels	Buffer organization
CH A	R1A
CH B	R1B
Both CH A and CH B	R1[ABAB. . .]
CH C	R1C
CH A and CH C	R1[ACAC. . .]
CH B and CH C	R1[BCBC. . .]
CH D	R1D
CH A and CH D	R1[ADAD. . .]
CH B and CH D	R1[BDBD. . .]
CH C and CH D	R1[CDCD. . .]
CH A, CH B, CH C and CH D	R1[ABCDABCD . . .]

See “%ATS_SDK_DIR%\Samples\DualPort\CS” for a sample program that demonstrates how to make an AutoDMA acquisition in continuous streaming mode.

Triggered streaming AutoDMA

Use triggered streaming mode to acquire a single, gapless record that spans two or more buffers after waiting for a trigger event to start the acquisition. The programmer specifies the number of samples in each buffer, and buffers in the acquisition. Each buffer is organized as follows if a board has on-board memory. R1x represents a contiguous array of samples from channel x.

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Enabled channels	Buffer organization
CH A	R1A
CH B	R1B
CH A and CH B	R1A, R1B
CH C	R1C
CH A and CH C	R1A, R1C
CH B and CH C	R1B, R1C
CH D	R1D
CH A and CH D	R1A, R1D
CH B and CH D	R1B, R1D
CH C and CH D	R1C, R1D
CH A, CH B, CH C and CH D	R1A, R2B, R1C, R1D

Each buffer is organized as follows if a board does not have on-board memory, or if sample interleave is enabled. R1x represents a contiguous array of samples from channel x, R1[uv] represents samples interleaved from channels u and v, and R1[uvyz] represents samples interleaved from channels u, v, y, and z.

Enabled channels	Buffer organization
CH A	R1A
CH B	R1B
Both CH A and CH B	R1[ABAB. . .]
CH C	R1C
CH A and CH C	R1[ACAC. . .]
CH B and CH C	R1[BCBC. . .]
CH D	R1D
CH A and CH D	R1[ADAD. . .]
CH B and CH D	R1[BDBD. . .]
CH C and CH D	R1[CDCD. . .]
CH A, CH B, CH C and CH D	R1[ABCDABCD . . .]

See “%ATS_SDK_DIR%\Samples\DualPort\TS” for a sample program that demonstrates how to make a triggered streaming AutoDMA acquisition.

Record headers and timestamps

In traditional AutoDMA mode, a 16-byte record header may optionally precede each record in a buffer. When record headers are enabled, the following table shows the buffer layout if a board has on-board memory. Record headers are not supported if a board does not have on-board memory. Rxy represents a contiguous array of samples from record x of channel y, and Hxy is a 16-byte record header from record x of channel y.

Enabled channels	Buffer organization
CH A	H1A, R1A, H2A, R2A . . . HnA, RnA
CH B	H1B, R1B, H2B, R2B . . . HnB, RnB
CH A and CH B	H1A, R1A, H1B, R1B, H2A, R2A, H2B, R2B. . . HnA, RnA, HnB, RnB
CH C	H1C, R1C, H2C, R2C . . . HnC, RnC
CH A and CH C	H1A, R1A, H1C, R1C, H2A, R2A, H2C, R2C. . . HnA, RnA, HnC, RnC
CH B and CH C	H1B, R1B, H1C, R1C, H2B, R2B, H2C, R2C. . . HnB, RnB, HnC, RnC
CH D	H1D, R1D, H2D, R2D . . . HnD, RnD
CH A and CH D	H1A, R1A, H1D, R1D, H2A, R2A, H2D, R2D. . . HnA, RnA, HnD, RnD
CH B and CH D	H1B, R1B, H1D, R1D, H2B, R2B, H2D, R2D. . . HnB, RnB, HnD, RnD
CH C and CH D	H1C, R1C, H1D, R1D, H2C, R2C, H2D, R2D. . . HnC, RnC, HnD, RnD
CH A, CH B, CH C and CH D	H1A, R1A, H1B, R1B, H1C, R1C, H1D, R1D, H2A, R2A, H2B, R2B H2C, R2C, H2D, R2D. . . HnA, RnA, HnB, RnB, HnC, RnC, HnD, RnD

Record headers

A record header is a 16-byte structure defined in AlazarApi.h as follows:

```
struct _HEADER0 {
  unsigned int SerialNumber:18; // bits 17..0
  unsigned int SystemNumber:4; // bits 21..18
  unsigned int WhichChannel:1; // bit 22
  unsigned int BoardNumber:4; // bits 26..23
  unsigned int SampleResolution:3; // bits 29..27
  unsigned int DataFormat:2; // bits 31..30
};

struct _HEADER1 {
  unsigned int RecordNumber:24; // bits 23..0
  unsigned int BoardType:8; // bits 31..24
};

struct _HEADER2 {
  U32 TimeStampLowPart; //bits 31..0
};

struct _HEADER3 {
  unsigned int TimeStampHighPart:8; // bits 7..0
  unsigned int ClockSource:2; // bits 9..8
  unsigned int ClockEdge:1; // bit 10
  unsigned int SampleRate:7; // bits 17..11
  unsigned int InputRange:5; // bits 22..18
  unsigned int InputCoupling:2; // bits 24..23
  unsigned int InputImpedence:2; // bits 26..25
  unsigned int ExternalTriggered:1; // bit 27
  unsigned int ChannelBTriggered:1; // bit 28
  unsigned int ChannelATriggered:1; // bit 29
  unsigned int TimeOutOccurred:1; // bit 30
  unsigned int ThisChannelTriggered:1; // bit 31
```

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```
};

typedef struct _ALAZAR_HEADER {
  struct _HEADER0 hdr0;
  struct _HEADER1 hdr1;
  struct _HEADER2 hdr2;
  struct _HEADER3 hdr3;
} *PALAZAR_HEADER;

typedef struct _ALAZAR_HEADER ALZAR_HEADER;
```

See ALAZAR_HEADER for more information about each of the fiels of this structure. See "%ATS_SDK_DIR%\Samples\DualPort\TR_Header" for a full sample program that demonstrates how to make an AutoDMA acquisition in Traditional mode with record headers.

Record timestamps

AlazarTech digitizer boards include a high-speed 40-bit counter that is clocked by the sample clock source scaled by a board specific divider. When a board receives a trigger event to capture a record to on-board memory, it latches the value of this counter. This timestamp value gives the time, relative to when the counter was reset, when the trigger event for this record occurred. By default, this counter is reset to zero at the start of each acquisition. Use AlazarResetTimeStamp() to control when the record timestamp counter is reset. The following code fragment demonstrates how to extract the timestamp from a record header, and covert the value from counts to seconds:

```
double samplesPerTimestampCount = 2; // board specific constant
double samplesPerSec = 100.e6; // sample rate
void* pRecord; // points to record header in buffer
ALAZAR_HEADER *pHeader = (ALAZAR_HEADER*) pRecord;
__int64 timestamp_counts;
timestamp_counts = (INT64) pHeader->hdr2.TimeStampLowPart;
timestamp_counts = timestamp_counts |
(((__int64) (pHeader->hdr3.TimeStampHighPart & 0x0ff)) << 32);
double timestamp_sec = samplesPerTimestampCount *
timestamp_counts / samplesPerSec;
```

Call AlazarGetParameter() with the GET_SAMPLES_PER_TIMESTAMP_CLOCK parameter to determine the board specific "samples per timestamp count" value. *Samples per record alignment requirements* lists these values. See "%ATS_SDK_DIR%\Samples\DualPort\TR_Header" for a full sample program that demonstrates how to make an AutoDMA acquisition in Traditional mode with record headers, and convert the timestamp to seconds.

AutoDMA acquisition flow

The AutoDMA functions allow an application to add user-defined number of buffers to a list of buffers available to be filled by a board, and to wait for the board to receive sufficient trigger events to fill the buffers with sample data. The board uses AutoDMA to transfer data directly into

a buffer without making any intermediate copies in memory. As soon as one buffer is filled, the driver automatically starts an AutoDMA transfer into the next available buffer.

AlazarPostBuffer

C/C++ applications should call `AlazarPostAsyncBuffer()` to make buffers available to be filled by the board, and `AlazarWaitAsyncBufferComplete()` to wait for the board to receive sufficient trigger events to fill the buffers. The following code fragment outlines the steps required to make an AutoDMA acquisition using `AlazarPostAsyncBuffer()` and `AlazarWaitAsyncBufferComplete()`:

```
// Configure the board to make an AutoDMA acquisition
AlazarBeforeAsyncRead(
  handle, // HANDLE -- board handle
  channelMask, // U32 -- enabled channel mask
  -(long)preTriggerSamples, // long -- trigger offset
  samplesPerRecord, // U32 -- samples per record
  recordsPerBuffer, // U32 -- records per buffer
  recordsPerAcquisition, // U32 -- records per acquisition
  flags // U32 -- AutoDMA mode and options
  );

// Add two or more buffers to a list of buffers
// available to be filled by the board
for (i = 0; i < BUFFER_COUNT; i++) {
  AlazarPostAsyncBuffer(
    handle, // HANDLE -- board handle
    BufferArray[i], // void* -- buffer pointer
    BytesPerBuffer // U32 -- buffer length in bytes
    );
}

// Arm the board to begin the acquisition
AlazarStartCapture(handle);

// Wait for each buffer in the acquisition to be filled
U32 buffersCompleted = 0;
while (buffersCompleted < buffersPerAcquisition) {
  // Wait for the board to receives sufficient trigger events
  // to fill the buffer at the head of its list of
  // available buffers.
  U32 bufferIndex = buffersCompleted % BUFFER_COUNT;
  U16* pBuffer = BufferArray[bufferIndex];
  AlazarWaitAsyncBufferComplete(handle, pBuffer, timeout_ms);
  buffersCompleted++;

  // The buffer is full, process it.
  // Note that while the application processes this buffer,
  // the board is filling the next available buffer
  // as trigger events arrive.
  ProcessBuffer(pBuffer, bytesPerBuffer);

  // Add the buffer to the end of the list of buffers
```

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```
  // available to be filled by this board. The board will
  // fill it with another segment of the acquisition after
  // all of the buffers preceding it have been filled.
  AlazarPostAsyncBuffer(handle, pBuffer, bytesPerBuffer);
}

// Abort the acquisition and release resources.
// This function must be called after an acquisition.
AlazarAbortAsyncRead(boardHandle);
```

See "%ATS_SDK_DIR%\Samples\DualPort\NPT" for a full sample program that demonstrates make an AutoDMA acquisition using AlazarPostAsyncBuffer.

ADMA_ALLOC_BUFERS

C#, and LabVIEW applications may find it more convenient to allow the API to allocate and manage a list of buffers available to be filled by the board. These applications should call AlazarBeforeAsyncRead() with the AMDA_ALLOC_BUFFERS option selected in the "Flags" parameter. This option will cause the API to allocate and manage a list of buffers available to be filled by the board. The application must call AlazarWaitNextAsyncBufferComplete() to wait for a buffer to be filled. When the board receives sufficient trigger events to fill a buffer, the API will copy the data from the internal buffer to the user-supplied buffer. The following code fragment outlines how make an AutoDMA acquisition using the ADMA_ALLOC_BUFFERS flag and AlazarWaitNextAsyncBufferComplete():

```
// Allow the API to allocate and manage AutoDMA buffers
flags |= ADMA_ALLOC_BUFFERS;

// Configure a board to make an AutoDMA acquisition
AlazarBeforeAsyncRead(
  handle, // HANDLE -- board handle
  channelMask, // U32 -- enabled channel mask
  -(long)preTriggerSamples, // long -- trigger offset
  samplesPerRecord, // U32 -- samples per record
  recordsPerBuffer, // U32 -- records per buffer
  recordsPerAcquisition, // U32 -- records per acquisition
  flags // U32 -- AutoDMA mode and options
  );

// Arm the board to begin the acquisition
AlazarStartCapture(handle);

// Wait for each buffer in the acquisition to be filled
RETURN_CODE retCode = ApiSuccess;
while (retCode == ApiSuccess) {
  // Wait for the board to receive sufficient
  // trigger events to fill an internal AutoDMA buffer.
  // The API will copy data from the internal buffer
  // to the user-supplied buffer.
  retCode =
```

```
  AlazarWaitNextAsyncBufferComplete(
    handle, // HANDLE -- board handle
    pBuffer, // void* -- buffer to receive data
    bytesToCopy, // U32 -- bytes to copy into buffer
    timeout_ms // U32 -- time to wait for buffer
    );

  // The buffer is full, process it
  // Note that while the application processes this buffer,
  // the board is filling the next available internal buffer
  // as trigger events arrive.
  ProcessBuffer(pBuffer, bytesPerBuffer);
}

// Abort the acquisition and release resources.
// This function must be called after an acquisition.
AlazarAbortAsyncRead(boardHandle);
```

See "%ATS_SDK_DIR%\Samples\DualPort\CS_WaitNextBuffer" for a full sample program that demonstrates make an AutoDMA acquisition using ADMA_ALLOC_BUFFERS. An application can get or set the number of DMA buffers allocated by the API by calling AlazarGetParameter() or AlazarSetParameter() with the parameter SETGET_ASYNC_BUFFCOUNT.

Note that applications may combine ADMA_ALLOC_BUFFERS with options to perform operations that would be difficult in high-level programming languages like LabVIEW. They include:

- Data normalization – This option enables the API to process sample data so that the data always has the same arrangement in the application buffer, independent of AutoDMA mode. See ADMA_GET_PROCESSED_DATA for more information.
- Disk streaming – This option allows the API to use high-performance disk I/O functions to stream buffer data to files. See AlazarCreateStreamFile() below for more information.

AlazarAsyncRead

Some C/C++ applications under Windows may require waiting for an event to be set to the signaled state to indicate when an AutoDMA buffer is full. These applications should use the AlazarAsyncRead() API. The following code fragment outlines how use AlazarAsyncRead() to make an asynchronous AutoDMA acquisition:

```
// Configure the board to make an AutoDMA acquisition
AlazarBeforeAsyncRead(
  handle, // HANDLE -- board handle
  channelMask, // U32 -- enabled channel mask
  -(long)preTriggerSamples, // long -- trigger ofset
  samplesPerBuffer, // U32 -- samples per buffer
  recordsPerBuffer, // U32 -- records per buffer
  recordsPerAcquisition, // U32 -- records per acquisition
  admaFlags // U32 -- AutoDMA flags
  );
```

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```
// Add two or more buffers to a list of buffers
// available to be filled by the board
for (i = 0; i < BUFFER_COUNT; i++) {
  AlazarAsyncRead (
    handle, // HANDLE -- board handle
    IoBufferArray[i].buffer, // void* -- buffer
    IoBufferArray[i].bytesPerBuffer, // U32 -- buffer length
    &IoBufferArray[i].overlapped // OVERLAPPED*
    );
}

// Arm the board to begin the acquisition
AlazarStartCapture(handle);

// Wait for each buffer in the acquisition to be filled.
U32 buffersCompleted = 0;
while (buffersCompleted < buffersPerAcquisition)
{
// Wait for the board to receives sufficient
// trigger events to fill the buffer at the head of its
// list of available buffers.
// The event handle will be set to the signaled state when
// the buffer is full.
U32 bufferIndex = buffersCompleted % BUFFER_COUNT;
IO_BUFFER *pIoBuffer = IoBufferArray[bufferIndex];
WaitForSingleObject(pIoBuffer->hEvent, INFINTE);
buffersCompleted++;

// The buffer is full, process it
// Note that while the application processes this buffer,
// the board is filling the next available buffer
// as trigger events arrive.
ProcessBuffer(pIoBuffer->buffer, pIoBuffer->bytesPerBuffer);

// Add the buffer to the end of the list of buffers.
// The board will fill it with another segment from the
// acquisition after the buffers preceding it have been filled.
AlazarAsyncRead (
handle, // HANDLE -- board handle
pIoBuffer->buffer, // void* -- buffer
pIoBuffer->bytesPerBuffer, // U32 -- buffer length
&pIoBuffer->overlapped // OVERLAPPED*
);
}

// Stop the acquisition. This function must be called if unfilled buffers are
// pending.
AlazarAbortAsyncRead(handle);
```

See “%ATS_SDK_DIR%\Samples\DualPort\CS_AsyncRead” for a full sample program that demonstrates make an AutoDMA acquisition using `AlazarAsyncRead()`.

AlazarAbortAsyncRead

The asynchronous API driver locks application buffers into memory so that boards may DMA directly into them. When a buffer is completed, the driver unlocks it from memory. An application must call `AlazarAbortAsyncRead()` if, at the end of an acquisition, any of the buffers that it supplies to a board have not been completed. `AlazarAbortAsyncRead()` completes any pending buffers, and unlocks them from memory.

Warning: If an application exits without calling `AlazarAbortAsyncRead()`, the API driver may generate a `DRIVER_LEFT_LOCKED_PAGES_IN_PROCESS (0x000000CB)` bug check error under Windows, or leak the locked memory under Linux. This may happen, for example, if a programmer runs an application that uses the API under a debugger, stops at a breakpoint, and then stops the debugging session without letting the application or API exit normally.

Buffer count

An application should supply at least two buffers to a board. This allows the board to fill one buffer while the application consumes the other. As long as the application can consume buffers faster than the board can fill them, the acquisition can continue indefinitely. However, Microsoft Windows and general-purpose Linux distributions are not real time operating systems. An application thread may be suspended for an indeterminate amount of time to allow other threads with higher priority to run. As a result, buffer processing may take longer than expected. The board is filling AutoDMA buffers with sample data in real time. If an application is unable to supply buffers as fast a board fills them, the board will run out of buffers into which it can transfer sample data. The board can continue to acquire data until it fills is on-board memory, but then it will abort the acquisition and report a buffer overflow error.

It is recommended that an application supply three or more buffers to a board. This allows some tolerance for operating system latencies. The programmer may need to increase the number of buffers according to the application.

Note: The number of buffers required by a board is not the same as the number of buffers required by an application. There may be little benefit in supplying a board with more than a few tens of buffers, each of a few million samples. If an application requires much more sample data for data analysis or other purposes, the programmer should consider managing application buffers separately from AutoDMA buffers.

Scanning applications

Scanning applications divide an acquisition into frames, where each frame is composed of a number of scan lines, and each scan line is composed of a number of sample points. These applications typically:

- Wait for a “start of frame” event.

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- Wait for a number of “start of line” events, capturing a specified number of sample points after each “start of line” event.
- Wait for the next “start of frame” event and repeat.

To implement a scanning application using a hardware “start of frame” signal:

- Connect a TTL signal that will serve as the “start of frame” event to the AUX I/O connector.
- Call `AlazarConfigureAuxIO()` specifying AUX_IN_TRIGGER_ENABLE as the mode, and the active edge of the trigger enable signal as the parameter.
- Configure the board to make an `NPT()` or `Traditional()` mode AutoDMA acquisition where the number of “records per buffer” is equal to the number of scan lines per frame.
- Call `AlazarStartCapture()` to being the acquisition.
- Supply a TTL pulse to the AUX I/O connector (or call `AlazarForceTriggerEnable()`) to arm the board to capture one frame. The board will wait for sufficient trigger events to capture the number of records in an AutoDMA buffer, and then wait for the next trigger enable event.

To implement a scanning application using a software “start of frame” command:

- Call `AlazarConfigureAuxIO()` specifying AUX_OUT_TRIGGER_ENABLE as the mode, along with the signal to output on the AUX I/O connector.
- Configure the board to make an `NPT()` or `Traditional()` mode AutoDMA acquisition where the number of “records per buffer” is equal to the number of scan lines per frame.
- Call `AlazarStartCapture()` to being the acquisition.
- Call `AlazarForceTriggerEnable()` to arm the board to capture one frame. The board will wait for sufficient trigger events to capture the number of records in an AutoDMA buffer, and then wait for the next trigger enable event.

Note that if the number of records per acquisition is set to infinite, software arms the digitizer once to make an AutoDMA acquisition with an infinite number of frames. The hardware will continue acquiring frame data until the acquisition is aborted. See “%ATS_SDK_DIR%\Samples\DualPort\NPT_Scan” for sample programs that demonstrate how to make a scanning application using hardware trigger enable signals.

Other scanning applications (NPT Footers)

In some other applications, an acquisition is divided several frames, but the number of records per frame is not constant. This happens in imaging applications such as intravascular OCT. The rotation speed of the imaging probe is not constant and the number of records (A-lines) may vary from one frame to the other.

For this situation, the AUX I/O connector should not be used as a trigger enable input as in conventional scanning application. Instead, it can be used a frame counter. The frame number can be appended to each data record so the used can recover the frame number for each record and then reconstruct each frame correctly. These are called footers and can only be used in NPT acquisition mode. See the NPT footers section for more details about using NPT footers.

Master-slave applications

If a dual-port acquisition API is used to acquire from master-slave board system:

- Call `AlazarBeforeAsyncRead()` on all slave boards before the master board.
- Call `AlazarStartCapture()` only on the master board.
- Call `AlazarAbortAsyncRead()` on the master board before the slave boards.
- The board system acquires the boards in the board system in parallel. As a result, an application must consume a buffer from each board in the board system during each cycle of the acquisition loop.
- Do not use synchronous API functions with master-slave systems – use the asynchronous API functions instead.

The following sample programs demonstrate how to acquire from a master-slave system: "%ATS_SDK_DIR%\Samples\DualPort\TR_MS", "%ATS_SDK_DIR%\Samples\DualPort\NPT_MS", "%ATS_SDK_DIR%\Samples\DualPort\CS_MS", and "%ATS_SDK_DIR%\Samples\DualPort\TS_MS".

Buffer size and alignment

AlazarTech digitizer boards must be configured to acquire a minimum number of samples per record, and each record must be a multiple of a specified number of samples. Records may shift within a buffer if aligment requirements are not met. Please refer to *Samples per record alignment requirements* for a list of requirements.

The number of pre-trigger samples in single-port and dual-port "traditional" AutoDMA mode must be a multiple of the pre-trigger aligment value above. See `AlazarSetRecordCount()` and `AlazarSetRecordSize()` for more information.

The address of application buffers passed to the following data transfer functions must meet the buffer aligment requirement in *Samples per record alignment requirements*: `AlazarRead()`, `AlazarReadEx()`, `AlazarAsyncRead()`, `AlazarPostAsyncBuffer()`, and `AlazarWaitAsyncBufferComplete()`. For example, the address of a buffer passed to AlazarPostAsyncBuffer to receive data from an ATS9350 must be aligned to a 32-sample, or 64-byte, address.

Note that `AlazarWaitNextAsyncBufferComplete()` has no aligment requirements. As a result, an application can use this function to transfer data if it is impossible to allocate correctly aligned buffers.

Data format

By default, AlazarTech digitizers generate unsigned sample data. For example, 8-bit digitizers such as the ATS9870 generate sample codes between 0 and 255 (0xFF) where: 0 represents a negative full-scale input voltage, 128 (0x80) represents ~0V input voltage, 255 (0xFF) represents a positive full-scale input voltage. Some AlazarTech digitizer can be configured to generate signed sample data in two's complement format. For example, the ATS9870 can be configured to generate sample

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codes where: 0 represents ~0V input voltage, 127 (0x7F) represents a positive full-scale input voltage, and –128 (0x80) represents a negative full-scale input voltage.

Call `AlazarSetParameter()` with parameter SET_DATA_FORMAT before the start of an acquisition to set the sample data format, and call `AlazarGetParameter()` with GET_DATA_FORMAT to get the current data format. The following code fragment demonstrates how to select signed sample data output:

```
AlazarSetParameter(
  handle, // HANDLE -- board handle
  0, // U8 -- channel Id (not used)
  SET_DATA_FORMAT, // U32 -- parameter to set
  DATA_FORMAT_SIGNED // long -- value (0 = unsigned, 1 = signed)
  );
```

Processing data

Converting sample values to volts

The data acquisition API's transfer an array of sample values into an application buffer. Each sample value occupies 1 or 2 bytes in the buffer, where a sample code is stored in the most significant bits of the sample values. Sample values that occupy two bytes are stored with their least significant bytes at the lower byte addresses (little-endian byte order) in the buffer. To convert sample values in the buffer to volts:

- Get a sample value from the buffer.
- Get the sample code from the most-significant bits of the sample value.
- Convert the sample code to volts.

Note that the arrangement of samples values in the buffer into records and channels depends on the API used to acquire the data.

- Single-port acquisitions return a contiguous array of samples for a specified channel. (See *Single Port Acquisition* above.)
- Dual-port AutoDMA acquisitions return sample data whose arrangement depends on the AutoDMA mode and options chosen. (See section *Dual port AutoDMA Acquisition* above.)

Also note that AlazarTech digitizer boards generate unsigned sample codes by default. (See *Data format* above.)

8-bits per sample

Getting 1-byte sample values from the buffer

The hexadecimal editor view below shows the first 128-bytes of data in a buffer from an 8-bit digitizer such as the ATS850, ATS860, ATS9850, and ATS9870.

```
00000  7F 7F 7F 7F 7F 7F 7F 7F   7F 7F 7F 7F 7F 7F 7F 7F
00010  7F 7F 7F 7F 7F 7F 7F 7F   7F 7F 7F 7F 7F 7F 7F 7F
00020  7F 7F 7F 7F 7F 7F 7F 7F   7F 7F 7F 7F 7F 7F 7F 7F
00030  7F 7F 7F 7F 7F 7F 7F 7F   7F 7F 7F 7F 7F 7F 7F 7F
00040  7F 7F 7F 7F 7F 7F 7F 7F   7F 7F 7F 7F 7F 7F 7F 7F
00050  7F 7F 7F 7F 7F 7F 7F 7F   7F 7F 7F 7F 7F 7F 7F 7F
00060  7F 7F 7F 7F 7F 7F 7F 7F   7F 7F 7F 7F 7F 7F 7F 7F
00070  7F 7F 7F 7F 7F 7F 7F 7F   7F 7F 7F 7F 7F 7F 7F 7F
```

Each 8-bit sample occupies 1-byte in the buffer, so the block above displays 128 samples (128 bytes / 1 byte per sample). The following code fragment demonstrates how to access each 8-bit sample value in a buffer:

```
U8 *pSamples = (U8*) buffer;
for (U32 sample = 0; sample < samplesPerBuffer; sample++) {
  U8 sampleValue = *pSamples++;
  printf("sample value = %02Xn", sampleValue);
}
```

Getting 8-bit sample codes from 1-byte sample values

Each 8-bit sample value stores an 8-bit sample code. For example, the first byte in buffer above stores the sample code 0x7F, or 127 decimal.

Converting unsigned 8-bit sample codes to volts

A sample code of 128 (0x80) represents ~0V input voltage, 255 (0xFF) represents a positive full-scale input voltage, and 0 represents a negative full-scale input voltage. The following table illustrates how unsigned 8-bit sample codes map to values in volts according to the full-scale input range of the input channel.

Hex value	Fraction of input range	Volts for ±100 mV range	Volts for ±1 V range
0x00	-100%	-100 mV	-1 V
0x40	-50%	-50 mV	-.5 V
0x80	0%	0 V	0V
0xC0	+50%	50 mV	+.5 V
0xFF	+100%	+100 mV	+1 V

The following code fragment shows how to convert a 1-byte sample value containing an unsigned 8-bit code to in volts:

```
double SampleToVoltsU8(U8 sampleValue, double inputRange_volts)
{
  // AlazarTech digitizers are calibrated as follows
  int bitsPerSample = 8;
  double codeZero = (1 << (bitsPerSample - 1)) - 0.5;
  double codeRange = (1 << (bitsPerSample - 1)) - 0.5;
  // Convert sample code to volts
```

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```
  double sampleVolts = inputRange_volts *
  ((double) (sampleValue - codeZero) / codeRange);
  return sampleVolts;
}
```

Converting signed 8-bit sample codes to volts

A signed code of 0 represents ~0V input voltage, 127 (0x7F) represents a positive full-scale input voltage, and –128 (0x80) represents a negative full-scale input voltage. The following table illustrates how signed 8-bit sample codes map to values in volts according to the full-scale input range of the input channel.

Hex value	Fraction of input range	Volts for ±100 mV range	Volts for ±1 V range
0x81	-100%	-100 mV	-1 V
0xC0	-50%	-50 mV	-.5 V
0x00	0%	0 V	0V
0x40	+50%	50 mV	+.5 V
0x7F	+100%	+100 mV	+1 V

The following code fragment shows how to convert a 1-byte sample value containing a signed 8-bit sample code to in volts:

```
double SampleToVoltsS8(U8 sampleValue, double inputRange_volts)
{
  // AlazarTech digitizers are calibrated as follows
  int bitsPerSample = 8;
  double codeZero = (1 << (bitsPerSample - 1)) - 0.5;
  double codeRange = (1 << (bitsPerSample - 1)) - 0.5;
  // Convert signed code to unsigned
  U8 sampleCode = sampleValue + 0x80;
  // Convert sample code to volts
  double sampleVolts = inputRange_volts *
  ((double) (sampleCode - codeZero) / codeRange);
  return sampleVolts;
}
```

12-bits per sample

Getting 2-byte sample values from the buffer

The hexadecimal editor view below displays the first 128-bytes of data in a buffer from a 12-bit digitizer such as the ATS310, ATS330, ATS9325, ATS9350, ATS9351, ATS9360, ATS9371, and ATS9373.

```
00000  E0 7F F0 7F 00 80 F0 7F   F0 7F 10 80 E0 7F 00 80
00010  F0 7F 00 80 E0 7F E0 7F   00 80 E0 7F F0 7F F0 7F
00020  E0 7F F0 7F 00 80 F0 7F   F0 7F 10 80 E0 7F 00 80
00030  F0 7F 00 80 E0 7F E0 7F   00 80 E0 7F F0 7F F0 7F
```

```
00040  E0 7F F0 7F 00 80 F0 7F   F0 7F 10 80 E0 7F 00 80
00050  F0 7F 00 80 E0 7F E0 7F   00 80 E0 7F F0 7F F0 7F
00060  E0 7F F0 7F 00 80 F0 7F   F0 7F 10 80 E0 7F 00 80
00070  F0 7F 00 80 E0 7F E0 7F   00 80 E0 7F F0 7F F0 7F
```

Each 12-bit sample value occupies a 2-bytes in the buffer, so the view above displays 64 sample values (128 bytes / 2 bytes per sample). The first 2 bytes in the buffer are 0xE0 and 0x7F. Two-byte sample values are stored in little-endian byte order in the buffer, so the first sample value in the buffer is 0x7FE0. The following code fragment demonstrates how to access each 16-bit sample value in a buffer:

```
U16 *pSamples = (U16*)buffer;
for (U32 sample = 0; sample < samplesPerBuffer; sample++) {
  U16 sampleValue = *pSamples++;
  printf("sample value = %04X\n", sampleValue);
}
```

Getting 12-bit sample codes from 16-bit sample values

A 12-bit sample code is stored in the most significant bits (MSB) of each 16-bit sample value, so right-shift each 16-bit value by 4 (or divide by 16) to obtain the 12-bit sample code. In the example above, the 16-bit sample value 0x7FE0 right-shifted by four results in the 12-bit sample code 0x7FE, or 2046 decimal.

16-bit sample value in decimal	32736
16-bit sample value in hex	7FE0
16-bit sample value in binary	0111 1111 1110 0000
12-bit sample code from MSBs of 16-bit value	0111 1101 1110
12-bit sample code in hex	7FE
12-bit sample code in decimal	2046

Converting unsigned 12-bit sample codes to volts

An unsigned code of 2048 (0x800) represents ~0V input voltage, 4095 (0xFFF) represents a positive full-scale input voltage, and 0 represents a negative full-scale input voltage. The following table illustrates how unsigned 12-bit sample codes map to values in volts according to the full-scale input range of the input channel.

Hex value	Fraction of input range	Volts for ±100 mV range	Volts for ±1 V range
0x000	-100%	-100 mV	-1 V
0x400	-50%	-50 mV	-.5 V
0x800	0%	0 V	0V
0xC00	+50%	50 mV	+.5 V
0xFFF	+100%	+100 mV	+1 V

The following code fragment demonstrates how to convert a 2-byte word containing an unsigned 12-bit sample code to in volts:

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```
double SampleToVoltsU12(U16 sampleValue, double inputRange_volts)
{
  // Right-shift 16-bit sample word by 4 to get 12-bit sample code
  int bitShift = 4;
  U16 sampleCode = sampeValue >> bitShift;
  // AlazarTech digitizers are calibrated as follows
  int bitsPerSample = 12;
  double codeZero = (1 << (bitsPerSample - 1)) - 0.5;
  double codeRange = (1 << (bitsPerSample - 1)) - 0.5;
  // Convert sample code to volts
  double sampleVolts = inputRange_volts *
  ((double) (sampleCode - codeZero) / codeRange);
  return sampleVolts;
}
```

Converting signed 12-bit sample codes to volts

A signed code of 0 represents ~0V input voltage, 2047 (0x7FF) represents a positive full-scale input voltage, and -2048 (0x800) represents a negative full-scale input voltage. The following table illustrates how signed 12-bit sample codes map to values in volts according to the full-scale input range of the input channel.

Hex value	Fraction of input range	Volts for ±100 mV range	Volts for ±1 V range
0x801	-100%	-100 mV	-1 V
0xC00	-50%	-50 mV	-.5 V
0x000	0%	0 V	0V
0x400	+50%	50 mV	+.5 V
0x7FF	+100%	+100 mV	+1 V

The following code fragment shows how to convert a 2-byte sample word containing a signed 12-bit sample code to in volts:

```
double SampleToVoltsS12(U16 sampleValue, double inputRange_volts)
{
  // Right-shift 16-bit sample value by 4 to get 12-bit sample code
  int bitShift = 4;
  U16 sampleCode = sampleValue >> bitShift;
  // Convert signed code to unsigned
  sampleCode = (sampleCode + 0x800) & 0x7FF;
  // AlazarTech digitizers are calibrated as follows
  int bitsPerSample = 12;
  double codeZero = (1 << (bitsPerSample - 1)) - 0.5;
  double codeRange = (1 << (bitsPerSample - 1)) - 0.5;
  // Convert sample code to volts
  double sampleVolts = inputRange_volts *
  ((double) (sampleCode - codeZero) / codeRange);
  return sampleVolts;
}
```

14-bits per sample

Getting 2-byte sample values from the buffer

The hexadecimal editor view below displays the first 128-bytes of data in a buffer from a 14-bit digitizer such as the ATS460 and ATS9440.

```
00000  4C 7F EC 7f 3c 80 98 80   D0 80 24 81 7C 81 B4 81
00010  3C 82 B4 82 A8 82 60 83   9C 83 14 84 40 84 88 84
00020  E0 84 50 85 D0 85 FC 85   2C 86 B0 86 10 87 56 87
00030  4C 7F EC 7f 3c 80 98 80   D0 80 24 81 7C 81 B4 81
00040  3C 82 B4 82 A8 82 60 83   9C 83 14 84 40 84 88 84
00050  E0 84 50 85 D0 85 FC 85   2C 86 B0 86 10 87 56 87
00060  4C 7F EC 7f 3c 80 98 80   D0 80 24 81 7C 81 B4 81
00070  E0 84 50 85 D0 85 FC 85   2C 86 B0 86 10 87 56 87
```

Each sample value occupies a 2-bytes in the buffer, so the figure displays 64 sample values (128 bytes / 2 bytes per sample). The first 2 bytes in the buffer, shown highlighted, are 0x4C and 0x7F. Two-byte sample values are stored in little-endian byte order in the buffer, so the first sample value in the buffer is 0x7F4C. The following code fragment demonstrates how to access each 16-bit sample value in a buffer:

```
U16 *pSamples = (U16*) buffer;
for (U32 sample = 0; sample < samplesPerBuffer; sample++) {
  U16 sampleValue = *pSamples++;
  printf("sample value = %04X\n", sampleValue);
}
```

Getting 14-bit sample codes from 16-bit sample values

A 14-bit sample code is stored in the most significant bits of each 16-bit sample value in the buffer, so right-shift each 16-bit value by 2 (or divide by 4) to obtain the 14-bit sample code. In the example above, the 16-bit value 0x7F4C right-shifted by two results in the 14-bit sample code 0x1FD3, or 8147 decimal.

16-bit sample value in decimal	32588
16-bit sample value in hex	7F4C
16-bit sample value in binary	0111 1111 0100 1100
14-bit sample code from MSBs of 16-bit sample value	01 1111 1101 0011
14-bit sample code in hex	1FD3
14-bit sample code in decimal	8147

Converting unsigned 14-bit sample codes to volts

An unsigned code of 8192 (0x2000) represents ~0V input voltage, 16383 (0x3FFF) represents a positive full-scale input voltage, and 0 represents a negative full-scale input voltage. The following

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table illustrates how unsigned 14-bit sample codes map to values in volts according to the full-scale input range of an input channel.

Hex value	Fraction of input range	Volts for ±100 mV range	Volts for ±1 V range
0x0000	-100%	-100 mV	-1 V
0x1000	-50%	-50 mV	-.5 V
0x2000	0%	0 V	0V
0x3000	+50%	50 mV	+.5 V
0x3FFF	+100%	+100 mV	+1 V

The following code fragment demonstrates how to convert a 2-byte sample value containing an unsigned 14-bit sample code to in volts:

```
double SampleToVoltsU14(U16 sampleValue, double inputRange_volts)
{
  // Right-shift 16-bit sample word by 2 to get 14-bit sample code
  int bitShift = 2;
  U16 sampleCode = sampleValue >> bitShift;
  // AlazarTech digitizers are calibrated as follows
  int bitsPerSample = 14;
  double codeZero = (1 << (bitsPerSample - 1)) - 0.5;
  double codeRange = (1 << (bitsPerSample - 1)) - 0.5;
  // Convert sample code to volts
  double sampleVolts = inputRange_volts *
  ((double) (sampleCode - codeZero) / codeRange);
  return sampleVolts;
}
```

Converting signed 14-bit sample codes to volts

A signed code of 0 represents ~0V input voltage, 8191 (0x1FFF) represents a positive full-scale input voltage, and –8192 (0x2000) represents a negative full-scale input voltage. The following table illustrates how signed 14-bit sample codes map to values in volts depending on the full-scale input range of the input channel.

Hex value	Fraction of input range	Volts for ±100 mV range	Volts for ±1 V range
0x2001	-100%	-100 mV	-1 V
0x3000	-50%	-50 mV	-.5 V
0x0000	0%	0 V	0V
0x1000	+50%	50 mV	+.5 V
0x1FFF	+100%	+100 mV	+1 V

The following code fragment demonstrates how to convert a 2-byte sample value containing a signed 14-bit sample code to in volts:

```
double SampleToVoltsU14(U16 sampleValue, double inputRange_volts)
{
  // Right-shift 16-bit sample word by 2 to get 14-bit sample code
  int bitShift = 2;
  U16 sampleCode = sampeWord >> bitShift;
  // AlazarTech digitizers are calibrated as follows
```

```
  int bitsPerSample = 14;
  double codeZero = (1 << (bitsPerSample - 1)) - 0.5;
  double codeRange = (1 << (bitsPerSample - 1)) - 0.5;
  // Convert the signed code to unsigned
  sampleCode = (sampleCode + 0x2000) & 0x1FFF;
  // Convert sample code to volts
  double sampleVolts = inputRange_volts *
  ((double) (sampleCode - codeZero) / codeRange);
  return sampleVolts;
}
```

16-bit per sample

Getting 2-byte sample values from the buffer

The hexadecimal editor view below displays the first 128-bytes of data in a buffer from a 16-bit digitizer such as the ATS660, ATS9462, ATS9625, or ATS9626.

> 00000 14 80 FB 7F FB 7F 08 80 FB 7F 00 80 02 80 ED 7F 00010 0B 80 FF 7F F8 7F 0B 80 09 80 0E 80 F3 7F FE 7F 00020 14 80 FB 7F FB 7F 08 80 FB 7F 00 80 02 80 ED 7F 00030 0B 80 FF 7F F8 7F 0B 80 09 80 0E 80 F3 7F FE 7F 00040 14 80 FB 7F FB 7F 08 80 FB 7F 00 80 02 80 ED 7F 00050 0B 80 FF 7F F8 7F 0B 80 09 80 0E 80 F3 7F FE 7F 00060 14 80 FB 7F FB 7F 08 80 FB 7F 00 80 02 80 ED 7F 00070 14 80 FB 7F FB 7F 08 80 FB 7F 00 80 02 80 ED 7F

Each 16-bit sample value occupies 2 bytes in the buffer, so the figure displays 64 sample values (128 bytes / 2 bytes per sample). The first 2 bytes in the buffer are 0x14 and 0x80. Two-byte samples values are stored in little-endian byte order in the buffer, so the first sample value is 0x8014. The following code fragment demonstrates how to access each 16-bit sample value in a buffer:

```
U16 *pSamples = (U16*)buffer;
for (U32 sample = 0; sample < samplesPerBuffer; sample++)
{
  U16 sampleValue = * pSamples++;
  printf("sample value = %04X\n", sampleValue);
}
```

Getting 16-bit sample codes from 16-bit sample values

A 16-bit sample code is stored in each 16-bit sample value in the buffer. In the example above, the first sample code is 0x8014, or 32788 decimal.

Converting unsigned 16-bit sample codes to volts

An unsigned code of 32768 (0x8000) represents ~0V input voltage, 65535 (0xFFFF) represents a positive full-scale input voltage, and 0 represents a negative full-scale input voltage. The following

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table illustrates how unsigned 16-bit sample codes map to values in volts according to the full-scale input range of an input channel.

Hex value	Fraction of input range	Volts for ±100 mV range	Volts for ±1 V range
0x0000	-100%	-100 mV	-1 V
0x4000	-50%	-50 mV	-.5 V
0x8000	0%	0 V	0V
0xC000	+50%	50 mV	+.5 V
0xFFFF	+100%	+100 mV	+1 V

The following code fragment demonstrates how to convert a 2-byte sample value containing an unsigned 16-bit sample code to in volts:

```
double SampleToVoltsU16(U16 sampleValue, double inputRange_volts)
{
  // AlazarTech digitizers are calibrated as follows
  int bitsPerSample = 16;
  double codeZero = (1 << (bitsPerSample - 1)) - 0.5;
  double codeRange = (1 << (bitsPerSample - 1)) - 0.5;
  // Convert sample code to volts
  double sampleVolts = inputRange_volts *
  ((double) (sampleValue - codeZero) / codeRange);
  return sampleVolts;
}
```

Converting signed 16-bit sample codes to volts

A signed code of 32767 (0x7FFF) represents a positive full-scale input voltage, 0 represents ~0V input voltage, and –32768 (0x8000) represents a negative full-scale input voltage. The following table illustrates how signed 16-bit sample codes map to values in volts according to the full-scale input range of the input channel:

Hex value	Fraction of input range	Volts for ±100 mV range	Volts for ±1 V range
0x8001	-100%	-100 mV	-1 V
0xC000	-50%	-50 mV	-.5 V
0x0000	0%	0 V	0V
0x4000	+50%	50 mV	+.5 V
0x7FFF	+100%	+100 mV	+1 V

The following code fragment demonstrates how to convert a 2-byte sample word containing a signed 16-bit sample code to in volts:

```
double SampleToVoltsS16(U16 sampleValue, double inputRange_volts)
{
  // AlazarTech digitizers are calibrated as follows
  int bitsPerSample = 16;
  double codeZero = (1 << (bitsPerSample - 1)) - 0.5;
  double codeRange = (1 << (bitsPerSample - 1)) - 0.5;
  // Convert signed sample value to unsigned code
  U16 sampleCode = (sampleValue + 0x8000);
  // Convert sample code to volts
```

```
  double sampleVolts = inputRange_volts *
  ((double) (sampleCode - codeZero) / codeRange);
  return sampleVolts;
}
```

Saving binary files

If an application saves sample data to a binary data file for later processing, it may be possible to improve disk write speeds by considering the following recommendations.

C/C++ applications

If the application is written in C/C++ and is running under Windows, use the Windows CreateFile API with the `FILE_FLAG_NO_BUFFERING` flag for file I/O, if possible. Sequential disk write speeds are often substantially higher when this option is selected. See "%ATS_SDK_DIR%\Samples\DualPort\TS_DisableFileCache" for a sample program that demonstrates how to use this API to stream data to disk.

LabVIEW applications

If the application is written in LabVIEW, or another high-level programming environment, then consider using the `AlazarCreateStreamFile()` API function. This function creates a binary data file, and enables the API to save each buffer received during an AutoDMA acquisition to this file. The API uses high-performance disk I/O functions that would be difficult to implement in high-level environments like LabVIEW. As a result, it allows an application in such an environment to perform high-performance disk streaming with a single additional function call. The following code fragment outlines how to write a disk streaming application using `AlazarCreateStreamFile()`:

```
// Allow the API to allocate and manage AutoDMA buffers
flags |= ADMA_ALLOC_BUFFERS;

// Configure the board to make an AutoDMA acquisition
AlazarBeforeAsyncRead(
  handle, // HANDLE -- board handle
  channelMask, // U32 -- enabled channel mask
  -(long)preTriggerSamples, // long -- trigger offset
  samplesPerRecord, // U32 -- samples per record
  recordsPerBuffer, // U32 -- records per buffer
  recordsPerAcquisition, // U32 -- records per acquisition
  flags // U32 -- AutoDMA mode and options
  );

// Create a binary data file, and enable the API save each
// AutoDMA buffer to this file.
AlazarCreateStreamFile(handle, "data.bin");

// Arm the board to begin the acquisition
```

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```
AlazarStartCapture(handle);

// Wait for each buffer in the acquisition to be filled
RETURN_CODE retCode = ApiSuccess;
while (retCode == ApiSuccess) {
  // Wait for the board to receive sufficient trigger
  // events to fill an internal buffer.
  // The API will save the buffer to a binary data file,
  // but will not copy any data into our buffer.
  retCode =
  AlazarWaitNextAsyncBufferComplete(
    handle, // HANDLE -- board handle
    NULL, // void* -- buffer to receive data
    0, // U32 -- bytes to copy into buffer
    timeout_ms // U32 -- time to wait for buffer
    );
}

// Abort the acquisition and release resources.
// This function must be called after an acquisition.
AlazarAbortAsyncRead(boardHandle);
```

See “%ATS_SDK_DIR%\Samples\DualPort\CS_CreateStreamFile” for a full sample program that demonstrates how to stream sample data to disk using AlazarCreateStreamFile().

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CHAPTER

THREE

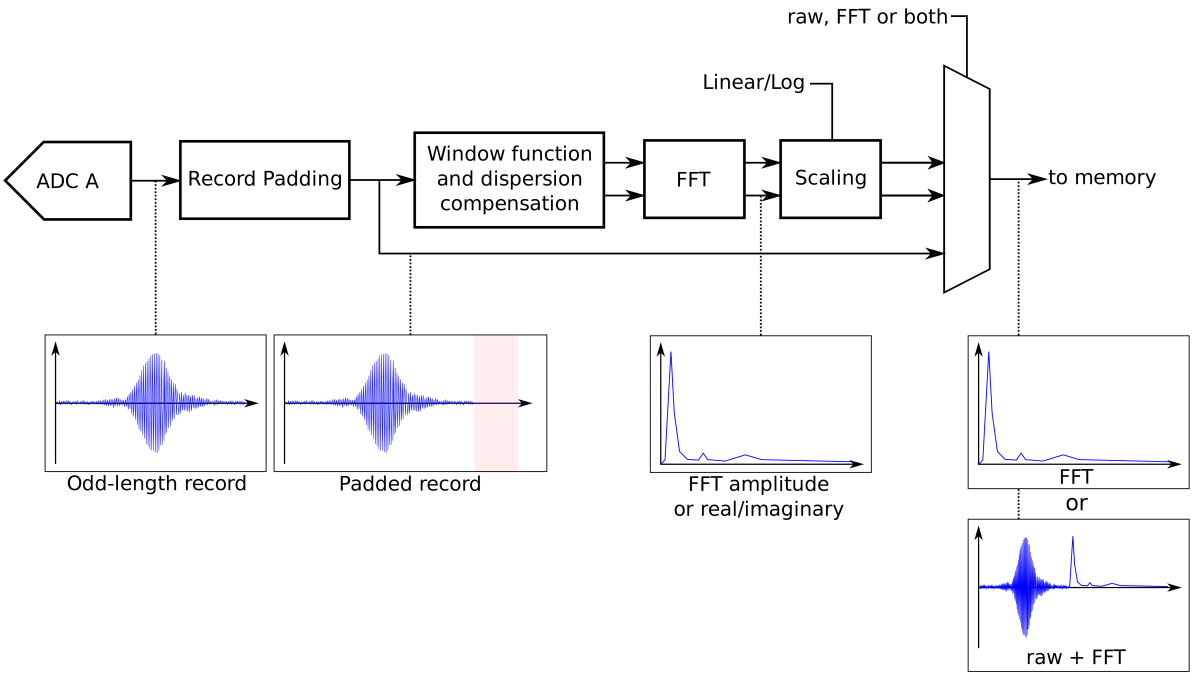
ALAZARDSP API DOCUMENTATION

This document presents the AlazarDSP API that allows accessing the on-board digital signal processing (DSP) features provided with some AlazarTech digitizers. Knowledge of the ATS-SDK API is required to take full advantage of the information presented here.

Introduction

On-FPGA FFT Overview

The first DSP module to make it into AlazarDSP is a Fast Fourier Transform (FFT) block implemented in `ATS9350`, `ATS9360`, `ATS9370`, `ATS9371` and `ATS9373`. This is a very versatile module that allows its users to compute the Fourier Transform of the input signal acquired on channel A, and to retrieve the processed data in a variety of output formats. The acquired records can be padded then mutiplied with a complex window function before going in the FFT processing block. The resulting data can optionaly be scaled to get its logarithm. The nature of the output data can be chosen (amplitude, real, imaginary), and it is then possible to set the output format from a variety of combinations (floating point, 32-bit unsigned integer, etc.). Lastly, it is possible to get at the output either FFT data, raw (time domain) data or both. The following diagram is a high-level overview of the FFT processing module.



General Programming Concepts

All the functions from the AlazarDSP module are defined in `AlazarDSP.h`, and are implemented in the usual `ATSApi` library (`ATSApi.dll` under Windows, and `libATSApi.so` under Linux).

Function are prefixed either with `AlazarDSP` if they apply to any DSP block, or by `AlazarFFT` if they are specific to fast Fourier transform modules.

The AlazarDSP API introduces a new type called `dsp_module_handle`, which represents a DSP module within a digitizer. Depending on their scope, function calls either require a board or a DSP module handle to be passed.

Note: The AlazarDSP functions *must* be used in the context of AutoDMA NPT applications.

Transition From Time-Domain Acquisitions

This section details all the steps that are required to take a working AutoDMA NPT program and turn it into a FFT program. These code samples can be found in AlazarTech's ATS-SDK

Function calls to the AlazarTech API are usually split into two categories: board configuration and data acquisition. This is best seen in the code samples provided with the ATS-SDK, where this separation is shown by sub-routines. Most of the AlazarDSP function calls fall into the second category. This means that the board configuration routine of the existing code samples is left mostly untouched.

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Programs that use the AlazarDSP API need to get the handle of the DSP module they want to use. This is done by calling AlazarDSPGetModules(). Information about the DSP module can be retrieved at any time using AlazarDSPGetInfo().

The board configuration section is left untouched when compared to a standard AutoDMA NPT acquisition.

In the data acquisition section, the following changes must be made:

1. AlazarSetRecordSize() is not called. This function is called internally by AlazarFFTSetup().
2. AlazarFFTSetup() is called before AlazarBeforeAsyncRead() and *before* allocating the DMA buffers. This is due to the fact that the number of bytes of data returned by the FFT engine may vary from one mode to the next, e.g. U16 log of amplitude output, U32 real part, etc. AlazarFFTSetup() returns the effective number of bytes per record that need to be allocated and passed to AlazarBeforeAsyncRead()
3. AlazarBeforeAsyncRead() is called by passing:
   (a) The number of *bytes* per record to the fourth parameter (*SamplesPerRecord*)
   (b) 0x7FFFFFFF to *RecordsPerAcquisition*
4. AlazarWaitAsyncBufferComplete() is replaced with AlazarDSPGetBuffer().
5. AlazarAbortAsyncRead() is replaced with AlazarDSPAbortCapture().

Detailed Description

DSP Module Variations

Features offered by DSP processing modules can vary from one board to another. An example of such variation is the maximum record size, which is generally lower on ATS9350 than on other board models. In order to query these information at runtime, AlazarDSP offers the AlazarDSPGetInfo() function. A generic interface to retrieve parameters has also been added with AlazarDSPGetParameterU32(). Each call to this function allows to retrieve one attribute of a DSP module. Available attributes to query are listed in DSP_PARAMETERS.

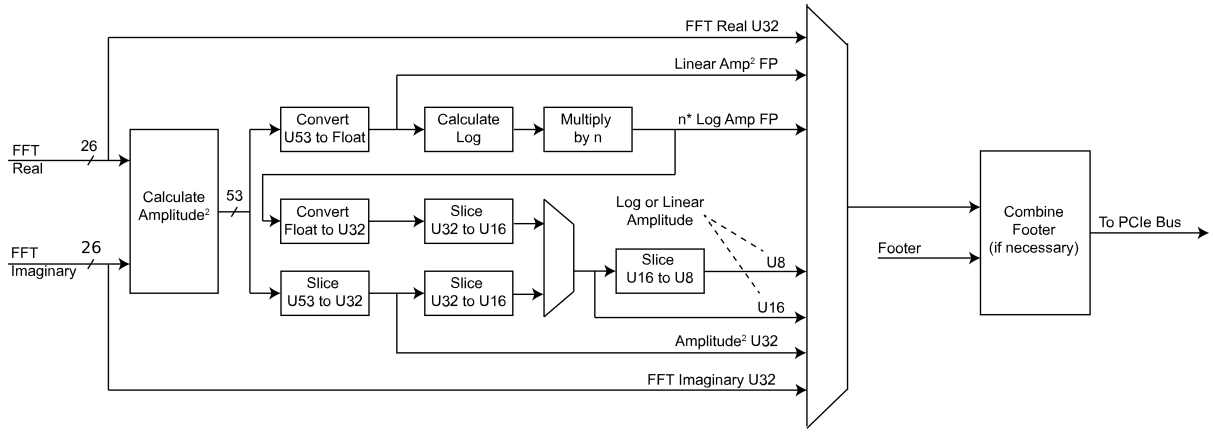
In addition, FFT module have specific parameters that are not indicated by AlazarDSPGetInfo(). For these modules, another introspection method is AlazarFFTGetMaxTriggerRepeatRate(). The maximum FFT input length can be read from the maxLength output parameter of AlazarDSPGetInfo().

FFT Module Output Data

The output data format of the FFT module is determined by the outputFormat parameter to AlazarFFTSetup(). This parameter can be any element of the FFT_OUTPUT_FORMAT enumeration except FFT_OUTPUT_FORMAT_RAW_PLUS_FFT, optionnaly OR'ed with FFT_OUTPUT_FORMAT_RAW_PLUS_FFT. The meaning of each element is described in FFT_OUTPUT_FORMAT.

If the RAW + FFT mode is selected, a number of samples that correspond to the FFT length is prepended to each record during the output. These samples contain the acquired time-domain data in U16 format, followed with padding to bring the number of samples to the FFT input length.

On the board, the Fourier Transform output is a 53-bit unsigned integer that gets converted in various blocks to match the requested output format. Along the conversion, it is possible to set a scaling a slicing parameter. These values are set to sane default in `AlazarFFTSetup()`. It is possible however for users to change these values manually, using the `AlazarFFTSetScalingAndSlicing()` function. The block diagram below shows where the conversions happen.



Background Subtraction

Starting with version 4.6, the on-FPGA FFT module offers a background subtraction feature. A record to subtract is downloaded on the board with `AlazarFFTBackgroundSubtractionSetRecordS16()`, and the feature is activated by `AlazarFFTBackgroundSubtractionSetEnabled()`.

Once background subtraction is enabled, the background is subtracted to all acquired time-domain records before they are sent in the FFT processing module.

It is not necessary to re-download the background record in between multiple acquisitions in the same program. The dowloaded record remains on the board. On the other hand, the default background record should not be assumed to be made of zeros. As the values *can* remain in the board, even after a reboot of the computer.

For 12-bit digitizers, the record is downloaded at 16 bits per sample, but only the 12 most significant bits are actually used. The 4 least significant bits are discarded. This behaviour is consistent with the way the boards acquire and send data back to user applications.

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API Reference

DSP-Specific Functions

RETURN_CODE **AlazarDSPAbortCapture**(HANDLE *boardHandle*)

Aborts any in-progress DMA transfer, cancels any pending transfers and does DSP-related cleanup.

This function should be called instead of *AlazarAbortAsyncRead()* in a standard acquisition configuration. In addition to handling pending and in-flight DMA transfers, it takes care of some cleanup related to the DSP post-processing.

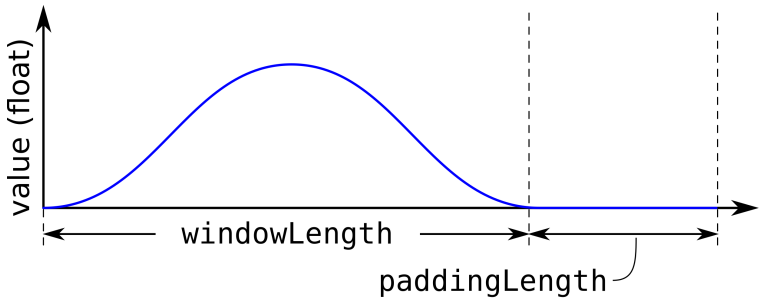
Warning Whereas it is not necessary to call *AlazarAbortAsyncRead()* to clean after a standard acquisition, calling *AlazarDSPAbortCapture()* is *strictly required*.

Parameters

- `boardHandle` - The board to stop the acquisition for.

RETURN_CODE **AlazarDSPGenerateWindowFunction**(U32 *windowType*, float **window*, U32 *windowLength_samples*, U32 *paddingLength_samples*)

Fills an array with a generated window function and pads it with zeros.



Please note that the windows length can take any integer value. It does not need to meet the alignment requirements that apply to the record length (see ATS-SDK guide), nor the power-of-two requirement of the FFT length. This can allow users a very high level of control over the effective acquired record length.

For example, if a laser source guarantees 1396 good data points at a particular frequency, the number of samples per record on ATS9360 should be set to 1408 (the next multiple of 128) and the FFT length should be 2048 points. The window function will be generated with a `windowLength_samples` of 1396, and a `paddingLength_samples` of 652 (2048 - 1396).

Return ApiSuccess upon sucess.

Parameters

- `windowType` - Type of window to generate. Pass an item from *DSP_WINDOW_ITEMS* enum.
- `window` - Array to be filled with the window function. It must be at least `windowLength_samples` + `paddingLength_samples` long.
- `windowLength_samples` - The size of the window to generate.
- `paddingLength_samples` - The number of samples after the window function to pad with zeros.

RETURN_CODE **AlazarDSPGetBuffer**(HANDLE *boardHandle*, void **buffer*, U32 *timeout_ms*)

Waits until a buffer becomes available or an error occurs.

This function should be called instead of *AlazarWaitAsyncBufferComplete()* in a standard acquisition configuration.

Parameters

- `boardHandle` - Board that filled the buffer we want to retrieve
- `buffer` - Pointer to the DMA buffer we want to retrieve. This must correspond to the first DMA buffer posted to the board that has not yet been retrieved.
- `timeout_ms` - Time to wait for the buffer to be ready before returning with an ApiWaitTimeout error.

RETURN_CODE **AlazarDSPGetInfo**(*dsp_module_handle dspHandle*, U32 **dspModuleId*, U16 **versionMajor*, U16 **versionMinor*, U32 **maxLength*, U32 **reserved0*, U32 **reserved1*)

Get information about a specific On-FPGA DSP implementation.

Use this function to query the type of a DSP module, as well as other information.

Return ApiSuccess upon success.

Parameters

- `dspHandle` - The handle to the DSP module to query.
- `dspModuleId` - The identifier of the DSP module. This describes what the type of this module is, and can be compared against the *DSP_MODULE_TYPE* enum.
- `versionMajor` - The major version number of the DSP implementation.
- `versionMinor` - The minor version number of the DSP implementation.
- `maxLength` - The maximum length of the records that can be processed.
- `reserved0` - Reserved parameter. Ignored
- `reserved1` - Reserved parameter. Ignored

RETURN_CODE **AlazarDSPGetModules**(HANDLE *boardHandle*, U32 *numEntries*, *dsp_module_handle* **modules*, U32 **numModules*)

Queries the list of DSP modules in a given board.

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This function allows to query the list of DSP modules for a digitizer board. `modules` is a pointer to an array of DSP modules to be filled by this function. The `numEntries` parameter specifies how many modules can be added by the function to the `modules` array. Lastly, the `numModules` array specifies how many modules are avaiable on the specified board.

`modules` can be `NULL`. In this case, the only interest of this function is to return the number of modules available. Please note that `numEntries` must be zero if `modules` is `NULL`.

`numModules` can be `NULL`. In this case, it is ignored.

This function is typically called twice. First without a `modules` array to query the number of available modules, and a second time after allocating an appropriate array.

```
U32 numModules;

U32 retCode = AlazarDSPGetModules(handle, 0, NULL, &numModules);

// Error handling

dsp_module_handle modules[numModules];

retCode = AlazarDSPGetModules(handle, numModules, modules, NULL);

// Error handling
```

Return ApiSuccess upon success.

Parameters

- `boardHandle` - The handle of the board to query DSP modules for.
- `numEntries` - The maximum number of entries that the function can fill in the `modules` array. Must be zero if `modules` is `NULL`.
- `modules` - The array where this function fills the `dsp_module_handle` elements. Can be `NULL`.
- `numModules` - Returns the number of DSP modules available on this board. Ignored if `NULL`.

RETURN_CODE **AlazarDSPGetNextBuffer**(HANDLE *boardHandle*, void **buffer*, U32 *bytesToCopy*, U32 *timeout_ms*)

Equivalent of *AlazarDSPGetBuffer()* to call with `ADMA_ALLOC_BUFFERS`.

This function should be called instead of *AlazarWaitNextAsyncBufferComplete()* in a standard acquisition configuration. See the documentation of this function for more information.

Parameters

- `boardHandle` - Board that filled the buffer we want to retrieve
- `buffer` - Pointer to a buffer to receive sample data from the digitizer board.
- `bytesToCopy` - The number of bytes to copy into the buffer.

- `timeout_ms` - Time to wait for the buffer to be ready before returning with an ApiWaitTimeout error.

RETURN_CODE **AlazarDSPGetParameterU32**(*dsp_module_handle* *dspHandle*, U32 *parameter*, U32 **result*)

Generic interface to retrieve U32-typed parameters.

This function is called with an element of DSP_PARAMETERS as `parameter`. Depending on which value is selected, the function will query a different parameter internally and pass the return value to `result`.

This function returns ApiSuccess upon success, and standard errors otherwise.

DSP-Specific Types and Enumerations

typedef struct dsp_module_descriptor ***dsp_module_handle**

enum DSP_MODULE_TYPE

DSP module type.

Used by *AlazarDSPGetInfo()*.

Values:

DSP_MODULE_NONE = 0xFFFF

DSP_MODULE_FFT

DSP_MODULE_PCD

DSP_MODULE_SSK

DSP_MODULE_DIS

Warning: doxygenenum: Cannot find enum "DSP_PARAMETERS" in doxygen xml output for project "alazardsp" from directory: ../doxygen_output/

enum DSP_WINDOW_ITEMS

Various types of window functions.

Used by *AlazarDSPGenerateWindowFunction()*.

Values:

DSP_WINDOW_NONE = 0

DSP_WINDOW_HANNING

DSP_WINDOW_HAMMING

DSP_WINDOW_BLACKMAN

DSP_WINDOW_BLACKMAN_HARRIS

DSP_WINDOW_BARTLETT

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NUM_DSP_WINDOW_ITEMS

FFT-Specific Functions

RETURN_CODE **AlazarFFTBackgroundSubtractionGetRecordS16**(*dsp_module_handle dspHandle*, S16 **backgroundRecord*, U32 *size_samples*)

Reads the background subtraction record from a board.

This function can be called to read which record the board uses for the background subtraction feature. It is used by allocating an array of the right size, then passing it to `backgroundRecord` along with it's size in samples to `size_samples`.

This function should be called before or between acquisitions, not during one.

RETURN_CODE **AlazarFFTBackgroundSubtractionSetEnabled**(*dsp_module_handle dspHandle*, BOOL *enabled*)

Controls the activation of the background subtraction feature.

Passing `true` to `enabled` activates background subtraction. Passing `false` deactivates it.

This function should be called before or between acquisitions, not during one.

RETURN_CODE **AlazarFFTBackgroundSubtractionSetRecordS16**(*dsp_module_handle dspHandle*, **const** S16 **record*, U32 *size_samples*)

Download the record for the background subration feature to a board.

Pass this function a pointer to an 16-bit integer array containing the record you want to download, and the size of this record in samples.

This function should be called before or between acquisitions, not during one.

RETURN_CODE **AlazarFFTGetMaxTriggerRepeatRate**(*dsp_module_handle dspHandle*, U32 *fftSize*, double **maxTriggerRepeatRate*)

Queries the maximum trigger repeat rate that the FFT engine can support without overflow.

This utility function is useful to calculate the theoretical maximum speed at which FFTs can be computed on a specific digitizer. The value returned only takes into account the FFT processing speed of the on-board module. Other parameters such as bus transfer speed must still be taken into account to ensure that an acquisition is possible on a given board.

Warning This function is available for FFT modules versions 4.5 and up.

Return ApiSucces upon success

Return ApiInvalidDspModule if the FFT module is invalid (wrong type or version)

Parameters

- `dspHandle` - The board for which to calculate the maximum trigger rate.
- `fftSize` - The number of points acquired by the board per FFT operation.

- `maxTriggerRepeatRate` - Output parameter that gets assigned the maximum trigger rate supported by this board's FFT processing module in Hertz.

RETURN_CODE **`AlazarFFTSetup`**(*dsp_module_handle dspHandle*, U16 *inputChannelMask*, U32 *recordLength_samples*, U32 *fftLength_samples*, U32 *outputFormat*, U32 *footer*, U32 *reserved*, U32 **bytesPerOutputRecord*)

Configure the board for an FFT acquisition.

This function needs to be called in the board configuration procedure, therefore before *AlazarBeforeAsyncRead()*.

The output format of the fft is controlled by the `outputFormat` parameter, with the `FFT_OUTPUT_FORMAT` enumeration. All elements of `FFT_OUTPUT_FORMAT` except `FFT_OUTPUT_FORMAT_RAW_PLUS_FFT` describe a data type (unsigned 8-bit integer, floating point number, etc.) as well as a scale (logarithmic or amplitude squared). It is mandatory to select one (and only one) of these.

On the other hand, when `FFT_OUTPUT_FORMAT_RAW_PLUG_FFT` is OR'ed (using the C | operator) to another symbol, it has the meaning of asking the board to output both the time-domain (raw) and FFT data.

Parameters

- `dspHandle` - The FFT module to configure.
- `inputChannelMask` - The channels to acquire data from. This must be `CHANNEL_A`.
- `recordLength_samples` - The number of points per record to acquire. This needs to meet the usual requirements for the number of samples per record. Please see the documentation of *AlazarBeforeAsyncRead()* for more information.
- `fftLength_samples` - The number of points per FFT. This value must be:
  - A power of two;
  - Greater than or equal to `recordLength_samples`;
  - Less than or equal to the maximum FFT size, as returned by the *AlazarDSPGetInfo()* function.
- `outputFormat` - Describes what data is output from the FFT post-processing module. This can be any element of the `FFT_OUTPUT_FORMAT` enum except `FFT_OUTPUT_FORMAT_RAW_PLUS_FFT`, optionnaly OR'ed with `FFT_OUTPUT_FORMAT_RAW_PLUS_FFT`.
- `footer` - Describes if a footer is attached to the returned records. Must be an element of the `FFT_FOOTER` enum.
- `reserved` - Reserved for future use. Pass 0.
- `bytesPerOutputRecord` - Returns the number of bytes in each record coming out of the FFT module. This value can be used to know how long the allocated DMA buffers must be.

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RETURN_CODE **AlazarFFTSetWindowFunction**(*dsp_module_handle dspHandle*, U32 *samplesPerRecord*, float **realWindowArray*, float **imagWindowArray*)

Sets the window function to use with an on-FPGA FFT module.

Downloads a window function to an AlazarTech digitizer's memory. This window function will be used during all subsequent acquisitions that use the on-FPGA DSP module.

This function should be called before *AlazarFFTSetup()*. It does not have to be called every time an acquisition is done. It can be located in the board configuration section.

Parameters

- `dspHandle` - The handle of the FFT DSP module to set the window function for.
- `samplesPerRecord` - The number of samples in the window function array.
- `realWindowArray` - The real window function array. Passing `NULL` is equivalent to passing an array filled with ones.
- `imagWindowArray` - The imaginary window function array. Passing `NULL` is equivalent to passing an array filled with zeros.

RETURN_CODE **AlazarFFTSetScalingAndSlicing**(*dsp_module_handle dspHandle*, U8 *slice_pos*, float *loge_ampl_mult*)

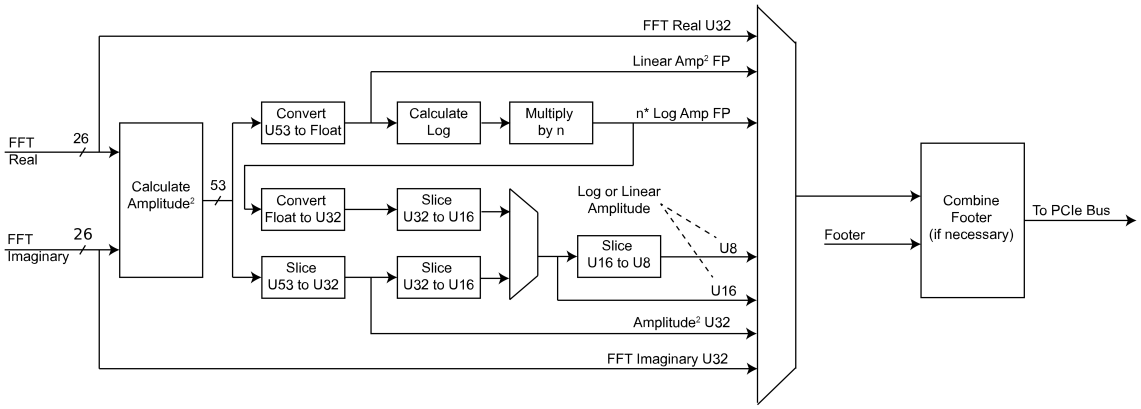
Sets internal scaling and slicing parameters in the FFT module.

This function modifies internal parameters used by the on-FPGA FFT module to convert the output of the FFT engine to the desired format. Please refer to the figure below for details as to where conversions happen.

Remark This function is only valid for on-FPGA FFT modules with version *less than* 5. For modules with version 5.0 and above, please refer to the various scaling parameters available in AlazarDSPSetParameterFloat() and AlazarDSPSetParameterS32().

Warning This function is intended for advanced users only. Calling it with the wrong parameters can prevent any meaningful data from being output by the FFT module.

To use this function in your program, it is necessary to call it **after** *AlazarFFTSetup()*, because this is where default scaling and slicing values are set.



Parameters

- `dspHandle` - Handle to DSP module
- `slice_pos` - This parameter indicates the position of the most significant bit of the output of slicing operations with respect to the input. Lowering this value by one has the effect of multiplying the output of the FFT module by 2. Default value is 7 for log outputs and 38 otherwise. On the block diagram, this parameter applies to all blocks marked 'Slice'.
- `loge_ampl_mult` - This controls a multiplicative factor used after the log conversion in the FFT module. Hence, it does not apply to 'amplitude squared' outputs. Default value is 4.3429446 for U8 log and float log outputs, and 1111.7938176 for U16 log output.

FFT-Specific Enumerations

enum `FFT_OUTPUT_FORMAT`

FFT output format enumeration.

Values:

`FFT_OUTPUT_FORMAT_U32_AMP2` = 0x0
32-bit unsigned integer amplitude squared output. Pre-DSP v5.0 only.

`FFT_OUTPUT_FORMAT_U16_LOG` = 0x1
16-bit unsigned integer logarithmic amplitude output. Pre-DSP v5.0 only.

`FFT_OUTPUT_FORMAT_U16_AMP2` = 0x101
16-bit unsigned integer amplitude squared output. Pre-DSP v5.0 only.

`FFT_OUTPUT_FORMAT_U8_LOG` = 0x2
8-bit unsigned integer logarithmic amplitude output. Pre-DSP v5.0 only.

`FFT_OUTPUT_FORMAT_U8_AMP2` = 0x102
8-bit unsigned integer amplitude squared output.

`FFT_OUTPUT_FORMAT_S32_REAL` = 0x3
32-bit signed integer real part of FFT output.

`FFT_OUTPUT_FORMAT_S32_IMAG` = 0x4
32-bit signed integer imaginary part of FFT output.

`FFT_OUTPUT_FORMAT_FLOAT_AMP2` = 0xA
32-bit floating point amplitude squared output.

`FFT_OUTPUT_FORMAT_FLOAT_LOG` = 0xB
32-bit floating point logarithmic output.

`FFT_OUTPUT_FORMAT_RAW_PLUS_FFT` = 0x1000
Prepend each FFT output record with a signed 16-bit version of the time-domain data.

`FFT_OUTPUT_FORMAT_S32_AMP2` = 0x400
32-bit signed integer amplitude squared output. DSP v5.0 and above only.

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FFT_OUTPUT_FORMAT_S32_LOG
32-bit signed integer logarithmic amplitude output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S32_PHASE
32-bit signed integer phase output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S16_REAL
16-bit signed integer real part of FFT output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S16_IMAG
16-bit signed integer imaginary part of FFT output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S16_LOG
16-bit signed integer logarithmic amplitude output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S16_AMP2
16-bit signed integer amplitude squared output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S16_PHASE
16-bit signed integer phase output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S8_REAL
8-bit signed integer real part of FFT output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S8_IMAG
8-bit signed integer imaginary part of FFT output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S8_LOG
8-bit signed integer logarithmic amplitude output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S8_AMP2
8-bit signed integer amplitude squared output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S8_PHASE
8-bit signed integer phase output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_FLOAT_REAL
32-bit floating point real part of FFT output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_FLOAT_IMAG
32-bit floating point imaginary part of FFT output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_FLOAT_PHASE
32-bit floating point phase output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S16_AMP2_AND_PHASE
16-bit signed integer amplitude squared plus phase output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S16_LOG_AND_PHASE
16-bit signed integer logarithmic amplitude plus phase output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_S16_REAL_AND_IMAG
16-bit signed integer real plus imaginary parts of FFT output. DSP v5.0 and above only.

FFT_OUTPUT_FORMAT_DEBUG_DP2_M5

FFT_OUTPUT_FORMAT_DEBUG_DP2_M6

FFT_OUTPUT_FORMAT_DEBUG_DP2_M7

INTERNAL_DECLARATIONS

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CHAPTER

FOUR

ADVANCED TOPICS

External clock issues for OCT applications

The external clocking feature of AlazarTech boards is commonly used in OCT applications, where swept laser sources generate a signal to be used for clocking the acquisition. However, in some cases the external clock signal does not meet the requirements of the digitizers, which can lead to various issues. This section discusses the steps that need to be taken to diagnose and troubleshoot external clock problems.

Diagnose external clock issues

External clock issues can be of two natures; trigger jumps, or unexpected (glitchy) acquired data. These issues can also arise as the result of a board misconfiguration (bad record length, bad trigger configuration...). Before proceeding with the external clock troubleshooting, you *must* ensure that the external clock is indeed the cause of your problems. One way to do that is to make sure that your acquisition works fine when using the internal clock. Another way is to reproduce your acquisition configuration in AlazarDSO, and make sure that the problem also shows up there. Once having made sure that the external clock is the issue, the next step is to identify the problematic regions of the signal. To do this, please acquire a few record acquisition cycles (laser sweeps) with a high speed oscilloscope (ideally 20GS/s, 4GHz), and to send the results to us.

Here is an example of an external clock analysis plot, annotated to show the problem:

K-clock deglitching firmware

The k-clock deglitching firmware available for ATS9350 and ATS9351 is specifically designed to overcome k-clock related issues. If you are using one of these boards, trying this firmware is the next logical step. In our experience, it solves all k-clock related issues. ATS9360, ATS9370, ATS9371 and ATS9373's firmwares include the deglitching feature by default.

AlazarSetTriggerOperationForScanning

AlazarTech digitizers require that the ADC clock be valid when an application calls `AlazarStartCapture()` to arm a board to begin an acquisition. The digitizer may not be able

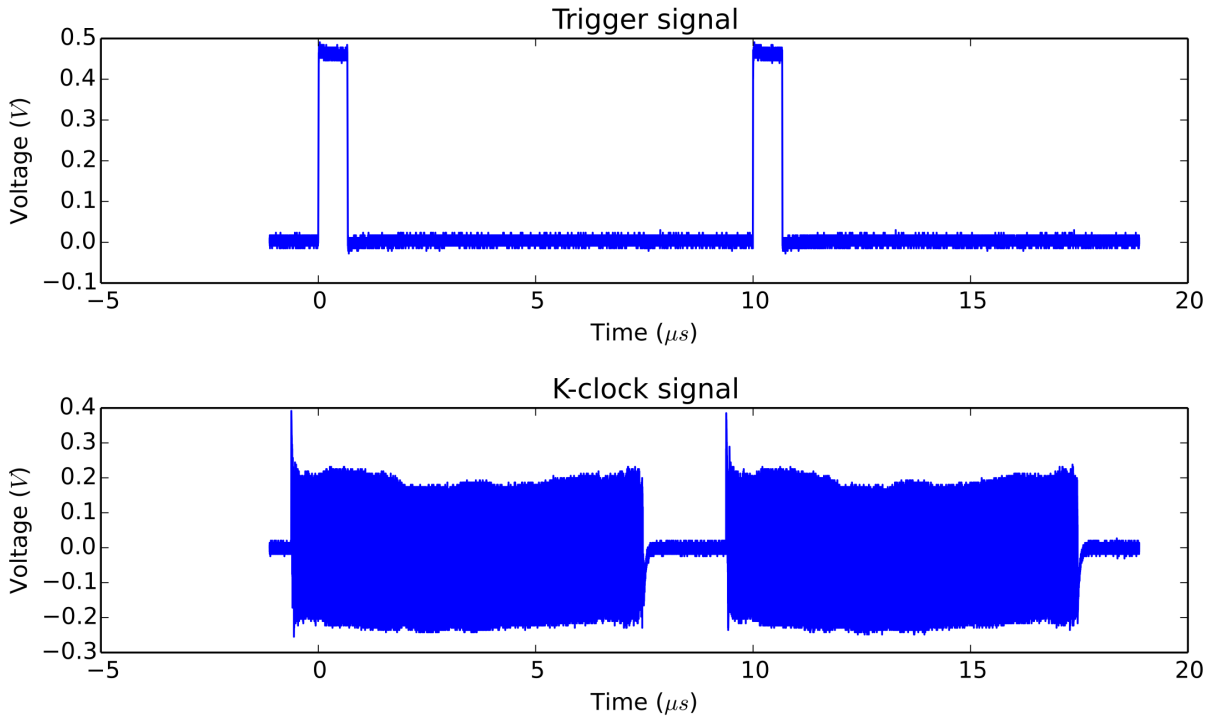

Fig. 4.1: External Clock Measurement

to start an acquisition if the the application calls `AlazarStartCapture()` while the ADC clock is invalid. If an application uses both external clock and external trigger signals, and the external clock is not suitable to drive the ADC's during part of the interval between trigger events, the application can call `AlazarSetTriggerOperationForScanning()` (rather than `AlazarSetTriggerOperation()`) to configure the trigger engines. This function configures the trigger engines to use an external trigger source connected to the TRIG IN connector, and also allows the board to begin an acquisition on the next external trigger event after the call to `AlazarStartCapture()`, when the external clock signal is valid.

For example, some OCT applications use a laser source that supplies an external clock signal that is valid on the rising edge of the trigger pulse, but falls to 0 Hz on the falling edge of the trigger pulse. The digitizer may not work correctly if the application calls `AlazarStartCapture()` to arm the board while the clock output is at 0 Hz. These applications can call `AlazarSetTriggerOperationForScanning()` to configure the trigger engines to use an external trigger input, and to wait until the first rising edge of the external trigger pulse arrives after the call the `AlazarStartCapture()` to start the acquisition, when the external clock is valid:

```
RETURN_CODE
AlazarSetTriggerOperationForScanning (
  HANDLE handle,
  U32 SlopeId, // trigger slope identifier
  U32 Level, // trigger level code
  U32 Options // scanning options
  );
```

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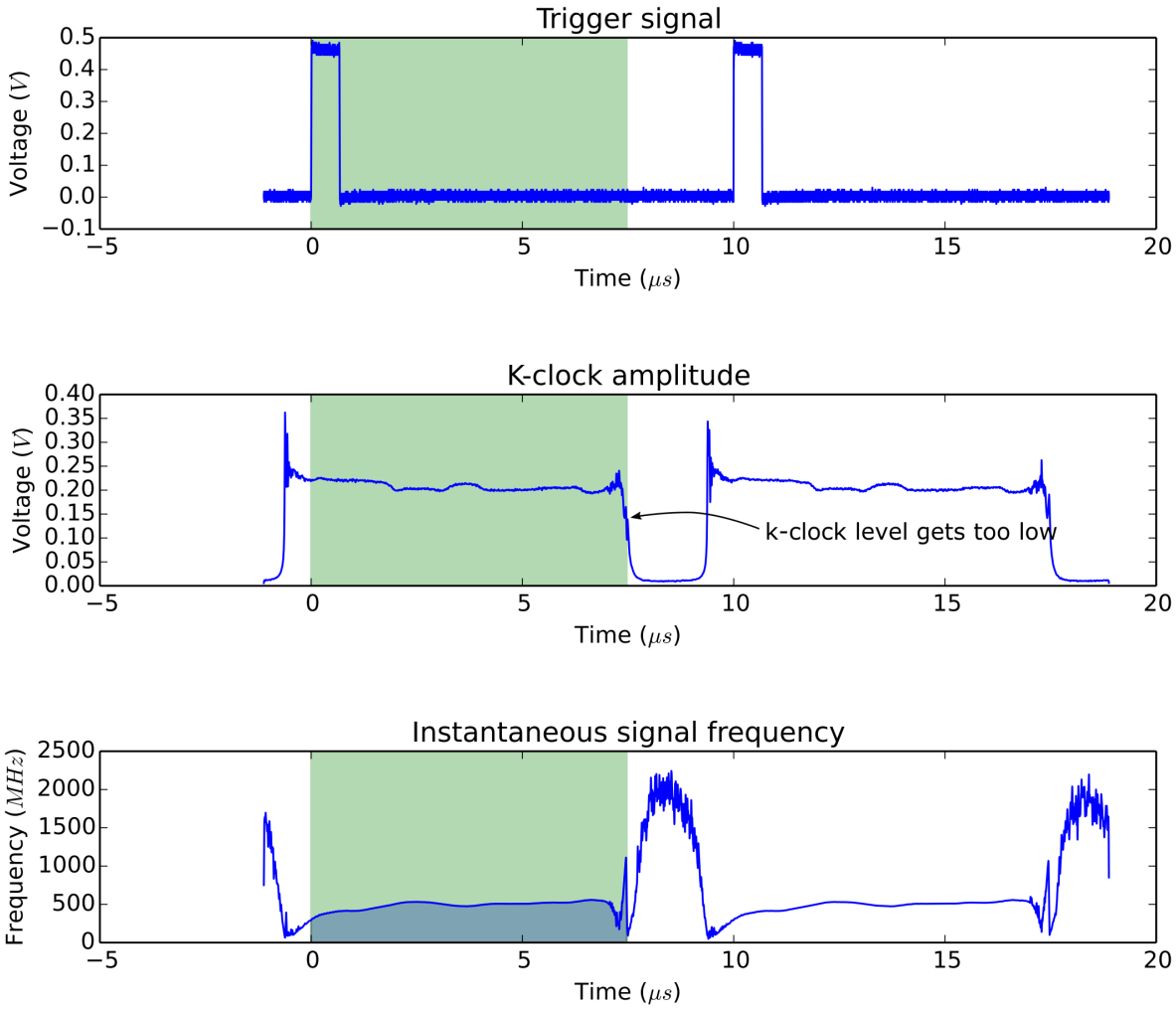

Fig. 4.2: Example of external clock analysis

`AlazarSetTriggerOperationForScanning()` configures a board to use trigger operation `TRIG_ENGINE_OP_J`, and configures the source of `TRIG_ENGINE_J` to be `TRIG_EXTERNAL`. The application must call `AlazarSetExternalTrigger()` to set the full-scale external input range and coupling of the external trigger signal connected to the TRIG IN connector. The slope identifier parameter selects if a trigger event should be generated when the external trigger level rise above, or falls below, a specified level. The parameter may have one of the following values.

`TRIGGER_SLOPE_POSITIVE` The external trigger level rises above a specified level.

`TRIGGER_SLOPE_NEGATIVE` The external trigger level falls below a specified level.

The trigger level parameter sets the external trigger level as an unsigned 8-bit code that represents a fraction of the external trigger full scale input range: 0 represents the negative full-scale input, 128 represents a 0 volt input, and 255 represents the positive full-scale input. In general, the trigger level value is given by:

```
TriggerLevelCode = 128 + 127 * TriggerLevelVolts / InputRangeVolts
```

The following table gives examples of how trigger level codes map to trigger levels in volts according to the external trigger full-scale input range.

Trigger level code	Input fraction	Level with ±1V trigger range	Level with ±5V trigger range
0	-100%	-1V	-5V
64	-50%	-500 mV	-2.5 V
96	-25%	-250 mV	-1.25 V
128	0%	0 V	0 V
160	+25 %	250 mV	1.25 V
192	+50%	+500 mV	+2.5 V
255	+100%	+1V	+5V

The options parameter may be one of the following flags:

`STOS_OPTION_DEFER_START_CAPTURE` Wait until the next external trigger event after the application calls `AlazarStartCapture()` before arming the board to start the acquisition. The external clock input should be valid when the trigger event arrives.

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CHAPTER

FIVE

API REFERENCE

Functions

RETURN_CODE **AlazarAbortAsyncRead**(HANDLE *handle*)
Aborts a dual-port acquisition, and any in-process DMA transfers.

This function is part of the dual-port API. It should be used only in this context. To abort single-port acquisitions using, see *AlazarAbortCapture()*.

Remark If you have started an acquisition and/or posted DMA buffers to a board, you *must* call *AlazarAbortAsyncRead()* before your application exits. If you do not, when your program exists, Microsoft Windows may stop with a blue screen error number `0x000000CB (DRIVER_LEFT_LOCKED_PAGES_IN_PROCESS)`. Linux may leak the memory used by the DMA buffers.

Parameters

- `handle` - Handle to board

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

RETURN_CODE **AlazarAbortCapture**(HANDLE *handle*)
Abort an acquisition to on-board memory.

This function is part of the single-port API. It should be used only in this context. To abort dual-port acquisitions, see *AlazarAbortAsyncRead()*.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle

U16 ***AlazarAllocBufferU16**(HANDLE *handle*, U32 *sampleCount*)
Allocates a buffer for DMA transfer for an 16-bit digitizer.

Return If the function is successful, it returns the base address of a page-aligned buffer in the virtual address space of the calling process. If it fails, it returns NULL.

Remark The buffer must be freed using *AlazarFreeBufferU16()*

Parameters

- `handle` - Handle to board
- `sampleCount` - Buffer size in samples

U8 ***AlazarAllocBufferU8**(HANDLE *handle*, U32 *sampleCount*)
Allocates a buffer for DMA transfer for an 8-bit digitizer.

Return If the function is successful, it returns the base address of a page-aligned buffer in the virtual address space of the calling process. If it fails, it returns NULL.

Remark The buffer must be freed using *AlazarFreeBufferU8()*

Parameters

- `handle` - Handle to board
- `sampleCount` - Buffer size in samples

U16 ***AlazarAllocBufferU16Ex**(HANDLE *handle*, U64 *sampleCount*)
This function acts like *AlazarAllocBufferU16()* and additionally allows allocation of a buffer over 4GS for DMA transfer for an 16-bit digitizer.

Return If the function is successful, it returns the base address of a page-aligned buffer in the virtual address space of the calling process. If it fails, it returns NULL.

Remark The buffer must be freed using *AlazarFreeBufferU16Ex()*

Parameters

- `handle` - Handle to board
- `sampleCount` - Buffer size in samples

U8 ***AlazarAllocBufferU8Ex**(HANDLE *handle*, U64 *sampleCount*)
This function acts like *AlazarAllocBufferU8()* and additionally allows allocation of a buffer over 4GS for DMA transfer for an 8-bit digitizer.

Return If the function is successful, it returns the base address of a page-aligned buffer in the virtual address space of the calling process. If it fails, it returns NULL.

Remark The buffer must be freed using *AlazarFreeBufferU8Ex()*

Parameters

- `handle` - Handle to board
- `sampleCount` - Buffer size in samples

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RETURN_CODE **AlazarBeforeAsyncRead**(HANDLE *handle*, U32 *channelSelect*, long *transferOffset*, U32 *transferLength*, U32 *recordsPerBuffer*, U32 *recordsPerAcquisition*, U32 *flags*)

Configure a board to make an asynchronous AutoDMA acquisition.

INTERNAL_DECLARATIONS In non-DSP mode, when record headers are not enabled, the total number of bytes per AutoDMA buffer is given by

```
bytesPerBuffer = bytesPerSample * samplesPerRecord * recordsPerBuffer;
```

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark `transferLength` must meet certain alignment criteria which depend on the board model and the acquisition type. Please refer to board-specific documentation for more information.

Remark `recordsPerBuffer` must be set to 1 in continuous streaming and triggered streaming AutoDMA modes.

Remark `recordsPerAcquisition` is ignored in Continuous Streaming and Triggered Streaming modes. Instead, the acquisition runs continuously until *AlazarAbortAsyncRead()* is called. In other modes, it must be either:

- A multiple of `recordsPerBuffer`
- `0x7FFFFFFF` to indicate that the acquisition should continue indefinitely.

Parameters

- `handle` - Handle to board
- `channelSelect` - Select the channel(s) to control. This can be one or more of the channels of *ALAZAR_CHANNELS*, assembled with the OR bitwise operator.
- `transferOffset` - Specify the first sample from each on-board record to transfer from on-board to host memory. This value is a sample relative to the trigger position in an on-board record.
- `transferLength` - Specify the number of samples from each record to transfer from on-board to host memory. In DSP-mode, it takes the number of bytes instead of samples. See remarks.
- `recordsPerBuffer` - The number of records in each buffer. See remarks.
- `recordsPerAcquisition` - The number of records to acquire during one acquisition. Set this value to `0x7FFFFFFF` to acquire indefinitely until the acquisition is aborted. This parameter is ignored in Triggered Streaming and Continuous Streaming modes. See remarks.
- `flags` - Specifies AutoDMA mode and option. Must be one element of ALAZAR_ADMA_MODES combined with zero or more element(s) of ALAZAR_ADMA_FLAGS using the bitwise OR operator.

When record headers are enabled, the formula changes to:

```
bytesPerBuffer = (16 + bytesPerSample * samplesPerRecord) *
                 recordsPerBuffer;
```

For best performance, AutoDMA parameters should be selected so that the total number of bytes per buffer is greater than about 1 MB. This allows for relatively long DMA transfer times compared to the time required to prepare a buffer for DMA transfer and re-arm the DMA engines.

ATS460, ATS660 and ATS860 digitizer boards require that AutoDMA parameters be selected so that the total number of bytes per buffer is less than 4 MB. Other boards require that the total number of bytes per buffer be less than 64 MB.

U32 **AlazarBoardsFound**()
Determine the number of digitizer boards that were detected in all board systems.

Return The total number of digitizer boards detected.

See *AlazarNumOfSystems()*

U32 **AlazarBoardsInSystemByHandle**(HANDLE *systemHandle*)
Return the number of digitizer boards in a board system specified by the handle of its master board.

If this function is called with the handle of to the master board in a master-slave system, it returns the total number of boards in the system.

If this function is called with the handle of an independent board, it returns 1.

If it is called with the handle to a slave in a master-slave system or with an invalid handle, it returns 0.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

U32 **AlazarBoardsInSystemBySystemID**(U32 *systemId*)
Returns the number of digitizer boards in a board system specified by its system identifier.

If this function is called with the identifier of a master-slave system, it returns the total number of boards in the system, including the master.

If this function is called with the identifier of an independent board system, it returns one.

If this fucntion is called with the identifier of an invalid board system, it returns zero.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `systemId` - The system identification number

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U32 **AlazarBusy**(HANDLE *handle*)
Determines if an acquisition is in progress.

Return If the board is busy acquiring data to on-board memory, this function returns 1. Otherwise, it returns 0.

Parameters

- `handle` - Board handle

void **AlazarClose**(HANDLE *handle*)
This routine will close the AUTODMA capabilities of the device.

Only call this upon exit or error.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle

RETURN_CODE **AlazarConfigureAuxIO**(HANDLE *handle*, U32 *mode*, U32 *parameter*)
Configures the AUX I/O connector as an input or output signal.

The AUX I/O connector generates TTL level signals when configured as an output, and expects TLL level signals when configured as an input.

Parameters

- `handle` - Handle to board
- `mode` - The AUX I/O mode. Can be selected from *ALAZAR_AUX_IO_MODES*. If an output mode is selected, the parameter may be OR'ed with AUX_OUT_TRIGGER_ENABLE to enable the board to use software trigger enable. When this flag is set, the board will wait for software to call *AlazarForceTriggerEnable()* to generate a trigger enable event; then wait for sufficient trigger events to capture the records in an AutoDMA buffer; then wait for the next trigger enable event and repeat.
- `parameter` - The meaning of this value varies depending on `mode`. See *ALAZAR_AUX_IO_MODES* for more details.

AUX I/O output signals may be limited by the bandwidth of the AUX output drivers.

The ATS9440 has two AUX I/O connectors: AUX 1 and AUX 2. AUX 1 is configured by firmware as a trigger output signal, while AUX 2 is configured by software using *AlazarConfigureAuxIO()*. A firmware update is required to change the operation of AUX 1.

ATS9625 and ATS9626 have two AUX I/O connectors; AUX 1 and AUX 2. AUX 1 is configured by software using *AlazarConfigureAuxIO()*, while AUX 2 is configured by default as a trigger output signal. A custom user-programmable FGPA can control the operation of AUX 2 as required by the FPGA designer.

To enable data skipping, first create a bitmap in memory that specifies which sample clock edges should generate a sample point, and which sample clock edges should be ignored.

- 1's in the bitmap specify the clock edges that should generate a sample point. The total number of 1's in the bitmap must be equal to the number of post-trigger samples per record specified in the call to AlazarSetRecordSize.
- 0's in the bitmap specify the clock edges that should not be used to generate a sample point.
- The total total number of bits in the bitmap is equal to the number of sample clocks in one record.

For example, to receive 16 samples from 32 sample clocks where every other sample clock is ignored, create a bitmap of 32 bits with values { 1 0 1 0 1 0 ... 1 0 }, or { 0x5555, 0x5555 }. Note that 16 of the 32 bits are 1's.

And to receive 24 samples from 96 sample clocks where data from every 3 of 4 samples clocks is ignored, create a bitmap of 96 bits with values { 1 0 0 0 1 0 0 0 1 0 0 0 ... 1 0 0 0 }, or in { 0x1111, 0x1111, 0x1111, 0x1111, 0x1111, 0x1111 }. Note that 24 of the 96 bits are 1's.

After creating a bitmap, call AlazarConfigureSampleSkipping with:

- Mode equal to SSM_ENABLE (1)
- SampleClocksPerRecord equal to the total number of sample clocks per record.
- pSampleSkipBitmap with the address of the U16 array.

To disable data skipping, call AlazarConfigureSampleSkipping with Mode equal to SSM_DISABLE (0). The SampleClocksPerRecord and pSampleSkipBitmap parameters are ignored.

Note that data skipping currently is supported by the ATS9371, ATS9373, ATS9360, ATS9350, ATS9351 and ATS9440. For ATS9440, data skipping only works with post-trigger data acquired at 125 MSPS or 100 MSPS.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

RETURN_CODE **AlazarConfigureLSB**(HANDLE *handle*, U32 *valueLsb0*, U32 *valueLsb1*)

Repurposes unused least significant bits in 12- and 14-bit boards.

12- and 14-bit digitizers return 16-bit sample values per sample by default, with the actual sample codes stored in the most significant bits. By default, the least significant bits of each sample value are zero-filled. Use this option to use these otherwise unused bits as digital outputs.

This feature is not available on all boards. See board-specific documentation for more information.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

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Parameters

- `handle` - Handle to board
- `valueLsb0` - Specifies the signal to output to the least significant bit of each sample value. Must be one of *ALAZAR_LSB*.
- `valueLsb1` - Specifies the signal to output to the least significant bit of each sample value. Must be one of *ALAZAR_LSB*.

RETURN_CODE **AlazarConfigureRecordAverage**(HANDLE *handle*, U32 *mode*, U32 *samplesPerRecord*, U32 *recordsPerAverage*, U32 *options*)

Configures a digitizer to co-add ADC samples from a specified number of records in an accumulator record, and transfer accumulator records rather than the ADC sample values.

When FPGA record averaging is enabled, the digitizer transfers one accumulator record to host memory after `recordsPerAverage` trigger events have been captured.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark FPGA record averaging is currently supported on the following digitizers:

- ATS9870 with FPGA version 180.0 and above, and driver version 5.9.8 and above
- AXI9870 with FPGA version 180.0 and above, and driver version 5.9.23 and above

Parameters

- `handle` - Handle to board
- `mode` - Averaging mode. Should be one element of ALAZAR_CRA_MODES.
- `samplesPerRecord` - The number of ADC samples per accumulator record.
- `recordsPerAverage` - The number of records to accumulate per average.
- `options` - The averaging options. Can be one of ALAZAR_CRA_OPTIONS.

Each accumulator record has interleaved samples from CH A and CH B. FPGA accumulators are 32-bit wide, so each accumulator value occupies 4 bytes in a buffer. The digitizer transfers multi-byte values in little-endian byte order.

CH A and CH B accumulator records are always transferred to host memory. As a result, the number of bytes per accumulator record is given by:

```
samplesPerRecord * 2 (channels) * 4 (bytes per accumulator sample)
```

The maximum value of `recordsPerAverage` for 8-bit digitizers is 16777215

Note that `recordsPerAverage` does not have to be equal to the number of records per buffer in AutoDMA mode.

RETURN_CODE **AlazarConfigureSampleSkipping**(HANDLE *handle*, U32 *mode*, U32 *sampleClocksPerRecord*, U16 **sampleSkipBitmap*)

Makes the digitizer sub-sample post trigger data in arbitrary, non-uniform intervals.

The application specifies which sample clock edges after a trigger event the digitizer should use to generate sample points, and which sample clock edges the digitizer should ignore.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `mode` - The data skipping mode. 0 means disable sample skipping and 1 means enable sample skipping.
- `sampleClocksPerRecord` - The number of sample clocks per record. This value cannot exceed 65536.
- `sampleSkipBitmap` - An array of bits that specify which sample clock edges should be used to capture a sample point (value = 1) and which should be ignored (value = 0).

RETURN_CODE **AlazarCoprocessorDownloadA**(HANDLE *handle*, char **fileName*, U32 *options*)
Downloads a FPGA image in RBF (raw binary file) format to the coprocessor FPGA.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `fileName` - Path to RBF file
- `options` - Download options chosen from *ALAZAR_COPROCESSOR_DOWNLOAD_OPTIONS*

RETURN_CODE **AlazarCoprocessorRegisterRead**(HANDLE *handle*, U32 *offset*, U32 **value*)
Reads the content of a user-programmable FPGA register.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `offset` - Register offset
- `value` - Address of a variable to receive the register's value

RETURN_CODE **AlazarCoprocessorRegisterWrite**(HANDLE *handle*, U32 *offset*, U32 *value*)
Writes a value to a user-programmable coprocessor FPGA register.

Return *ApiSuccess* upon success

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Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `offset` - Register offset
- `value` - Value to write

RETURN_CODE **`AlazarCreateStreamFile`**(HANDLE *handle*, **const** char **filePath*)

Creates a binary data file for this board, and enables saving AutoDMA data from thie board to disk.

If possible, select *AlazarBeforeAsyncRead()* parameters that result in DMA buffers whose length in bytes is evenly divisible into sectors of the volume selected by `filePath`. If the DMA buffer length is evenly divisible into records, *AlazarCreateStreamFile()* disables file caching to obtain the highest possible sequential write performance.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `filePath` - Pointer to a NULL-terminated string that specifies the name of the file.

An AutoDMA buffer is saved to disk when an application calls AlazarWaitNextAsyncBuferComplete(). For best performance, set the `bytesToCopy` parameter in AlazarWaitNextAsyncBuferComplete() to zero so that data is written to disk without copying it to the user-supplied buffer.

This function must be called after *AlazarBeforeAsyncRead()* and before *AlazarStartCapture()*. File streaming is only active for the acquisition that is about to start when this function is called. You should call this function again for each acquisition with which you want file streaming.

RETURN_CODE **`AlazarDSPAbortCapture`**(HANDLE *boardHandle*)

Aborts any in-progress DMA transfer, cancels any pending transfers and does DSP-related cleanup.

This function should be called instead of *AlazarAbortAsyncRead()* in a standard acquisition configuration. In addition to handling pending and in-flight DMA transfers, it takes care of some cleanup related to the DSP post-processing.

Warning Whereas it is not necessary to call *AlazarAbortAsyncRead()* to clean after a standard acquisition, calling *AlazarDSPAbortCapture()* is *strictly required*.

Parameters

- `boardHandle` - The board to stop the acquisition for.

RETURN_CODE **AlazarDSPGetBuffer**(HANDLE *boardHandle*, void **buffer*, U32 *timeout_ms*)
Waits until a buffer becomes available or an error occurs.

This function should be called instead of *AlazarWaitAsyncBufferComplete()* in a standard acquisition configuration.

Parameters

- `boardHandle` - Board that filled the buffer we want to retrieve
- `buffer` - Pointer to the DMA buffer we want to retrieve. This must correspond to the first DMA buffer posted to the board that has not yet been retrieved.
- `timeout_ms` - Time to wait for the buffer to be ready before returning with an ApiWaitTimeout error.

RETURN_CODE **AlazarDSPGetModules**(HANDLE *boardHandle*, U32 *numEntries*, *dsp_module_handle* **modules*, U32 **numModules*)
Queries the list of DSP modules in a given board.

This function allows to query the list of DSP modules for a digitizer board. `modules` is a pointer to an array of DSP modules to be filled by this function. The `numEntries` parameter specifies how many modules can be added by the function to the `modules` array. Lastly, the `numModules` array specifies how many modules are avaiable on the specified board.

`modules` can be `NULL`. In this case, the only interest of this function is to return the number of modules available. Please note that `numEntries` must be zero if `modules` is `NULL`.

`numModules` can be `NULL`. In this case, it is ignored.

This function is typically called twice. First without a `modules` array to query the number of available modules, and a second time after allocating an appropriate array.

```
U32 numModules;

U32 retCode = AlazarDSPGetModules(handle, 0, NULL, &numModules);

// Error handling

dsp_module_handle modules[numModules];

retCode = AlazarDSPGetModules(handle, numModules, modules, NULL);

// Error handling
```

Return ApiSuccess upon success.

Parameters

- `boardHandle` - The handle of the board to query DSP modules for.
- `numEntries` - The maximum number of entries that the function can fill in the `modules` array. Must be zero if `modules` is `NULL`.

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- `modules` - The array where this function fills the `dsp_module_handle` elements. Can be `NULL`.
- `numModules` - Returns the number of DSP modules available on this board. Ignored if `NULL`.

RETURN_CODE **AlazarDSPGetNextBuffer**(HANDLE *boardHandle*, void **buffer*, U32 *bytesToCopy*, U32 *timeout_ms*)

Equivalent of *AlazarDSPGetBuffer()* to call with `ADMA_ALLOC_BUFFERS`.

This function should be called instead of *AlazarWaitNextAsyncBufferComplete()* in a standard acquisition configuration. See the documentation of this function for more information.

Parameters

- `boardHandle` - Board that filled the buffer we want to retrieve
- `buffer` - Pointer to a buffer to receive sample data from the digitizer board.
- `bytesToCopy` - The number of bytes to copy into the buffer.
- `timeout_ms` - Time to wait for the buffer to be ready before returning with an ApiWaitTimeout error.

RETURN_CODE **AlazarDSPGetInfo**(*dsp_module_handle dspHandle*, U32 **dspModuleId*, U16 **versionMajor*, U16 **versionMinor*, U32 **maxLength*, U32 **reserved0*, U32 **reserved1*)

Get information about a specific On-FPGA DSP implementation.

Use this function to query the type of a DSP module, as well as other information.

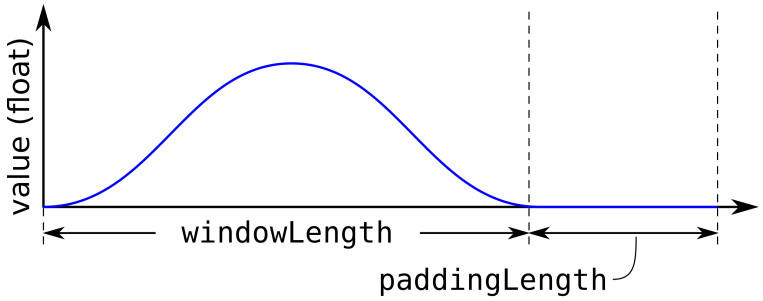
Return ApiSuccess upon success.

Parameters

- `dspHandle` - The handle to the DSP module to query.
- `dspModuleId` - The identifier of the DSP module. This describes what the type of this module is, and can be compared against the *DSP_MODULE_TYPE* enum.
- `versionMajor` - The major version number of the DSP implementation.
- `versionMinor` - The minor version number of the DSP implementation.
- `maxLength` - The maximum length of the records that can be processed.
- `reserved0` - Reserved parameter. Ignored
- `reserved1` - Reserved parameter. Ignored

RETURN_CODE **AlazarDSPGenerateWindowFunction**(U32 *windowType*, float **window*, U32 *windowLength_samples*, U32 *paddingLength_samples*)

Fills an array with a generated window function and pads it with zeros.



Please note that the windows length can take any integer value. It does not need to meet the alignment requirements that apply to the record length (see ATS-SDK guide), nor the power-of-two requirement of the FFT length. This can allow users a very high level of control over the effective acquired record length.

For example, if a laser source guarantees 1396 good data points at a particular frequency, the number of samples per record on ATS9360 should be set to 1408 (the next multiple of 128) and the FFT length should be 2048 points. The window function will be generated with a `windowLength_samples` of 1396, and a `paddingLength_samples` of 652 (2048 - 1396).

Return ApiSuccess upon sucess.

Parameters

- `windowType` - Type of window to generate. Pass an item from *DSP_WINDOW_ITEMS* enum.
- `window` - Array to be filled with the window function. It must be at least `windowLength_samples` + `paddingLength_samples` long.
- `windowLength_samples` - The size of the window to generate.
- `paddingLength_samples` - The number of samples after the window function to pad with zeros.

const char ***AlazarErrorToText**(*RETURN_CODE retCode*)

Converts a numerical return code to a NULL terminated string.

Return A string containing the identifier name of the error code

Remark It is often easier to work with a descriptive error name than an error number.

Parameters

- `retCode` - Return code from an AlazarTech API function

RETURN_CODE **AlazarExtractFFTNPTFooters**(void **buffer*, U32 *recordSize_bytes*, U32 *buffer-Size_bytes*, NPTFooter **footersArray*, U32 *numFootersToExtract*)

Extracts NPT footers from a buffer acquired during an FFT acquisition.

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Before calling this function, it is important to make sure that the buffers have been acquired in NPT mode with the NPT footers active. In addition, the acquisition *must* have used on-FPGA FFT computation.

Warning `footersArray` must contain at least `numFootersToExtract` elements.

Parameters

- `buffer` - Base address of the DMA buffer to process
- `recordSize_bytes` - Bytes per record in the DMA buffer passed as argument as returned by *AlazarFFTSetup()*.
- `bufferSize_bytes` - Bytes per buffer in the DMA buffer passed as argument
- `footersArray` - Base address of an array of NPTFooter structures which will be filled by this function
- `numFootersToExtract` - Maximum numbers of footers to extract. This can be a number from zero to the number of records in the DMA buffer passed as argument.

RETURN_CODE **AlazarExtractTimeDomainNPTFooters**(void **buffer*, U32 *recordSize_bytes*, U32 *bufferSize_bytes*, NPTFooter **footersArray*, U32 *numFootersToExtract*)

Extracts NPT footers from a buffer acquired during a time-domain acquisition.

Before calling this function, it is important to make sure that the buffers have been acquired in NPT mode with the NPT footers active. In addition, the acquisition must *not* have used on-FPGA FFT computation.

Warning `footersArray` must contain at least `numFootersToExtract` elements.

Parameters

- `buffer` - Base address of the DMA buffer to process
- `recordSize_bytes` - Bytes per record in the DMA buffer passed as argument
- `bufferSize_bytes` - Bytes per buffer in the DMA buffer passed as argument
- `footersArray` - Base address of an array of NPTFooter structures which will be filled by this function
- `numFootersToExtract` - Maximum numbers of footers to extract. This can be a number from zero to the number of records in the DMA buffer passed as argument.

RETURN_CODE **AlazarExtractNPTFooters**(void **buffer*, U32 *recordSize_bytes*, U32 *bufferSize_bytes*, NPTFooter **footersArray*, U32 *numFootersToExtract*)

Extracts NPT footers from a buffer that contains them.

Before calling this function, it is important to make sure that the buffers have been acquired in NPT mode with the NPT footers active.

Warning This function has been deprecated in favor of *AlazarExtractTimeDomainNPTFooters()* and *AlazarExtractFFTNPTFooters()*. It is still usable, but only works on NPT footers acquired as part of an FFT acquisition.

Warning `footersArray` must contain at least `numFootersToExtract` elements.

Parameters

- `buffer` - Base address of the DMA buffer to process
- `recordSize_bytes` - Bytes per record in the DMA buffer passed as argument
- `bufferSize_bytes` - Bytes per buffer in the DMA buffer passed as argument
- `footersArray` - Base address of an array of NPTFooter structures which will be filled by this function
- `numFootersToExtract` - Maximum numbers of footers to extract. This can be a number from zero to the number of records in the DMA buffer passed as argument.

RETURN_CODE **AlazarFFTSetup**(*dsp_module_handle dspHandle*, U16 *inputChannelMask*, U32 *recordLength_samples*, U32 *fftLength_samples*, U32 *outputFormat*, U32 *footer*, U32 *reserved*, U32 **bytesPerOutputRecord*)

Configure the board for an FFT acquisition.

This function needs to be called in the board configuration procedure, therefore before *AlazarBeforeAsyncRead()*.

The output format of the fft is controlled by the `outputFormat` parameter, with the `FFT_OUTPUT_FORMAT` enumeration. All elements of `FFT_OUTPUT_FORMAT` except `FFT_OUTPUT_FORMAT_RAW_PLUS_FFT` describe a data type (unsigned 8-bit integer, floating point number, etc.) as well as a scale (logarithmic or amplitude squared). It is mandatory to select one (and only one) of these.

On the other hand, when `FFT_OUTPUT_FORMAT_RAW_PLUG_FFT` is OR'ed (using the C | operator) to another symbol, it has the meaning of asking the board to output both the time-domain (raw) and FFT data.

Parameters

- `dspHandle` - The FFT module to configure.
- `inputChannelMask` - The channels to acquire data from. This must be `CHANNEL_A`.
- `recordLength_samples` - The number of points per record to acquire. This needs to meet the usual requirements for the number of samples per record. Please see the documentation of *AlazarBeforeAsyncRead()* for more information.
- `fftLength_samples` - The number of points per FFT. This value must be:
  - A power of two;
  - Greater than or equal to `recordLength_samples`;

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  - Less than or equal to the maximum FFT size, as returned by the *AlazarDSPGetInfo()* function.

- `outputFormat` - Describes what data is output from the FFT post-processing module. This can be any element of the `FFT_OUTPUT_FORMAT` enum except `FFT_OUTPUT_FORMAT_RAW_PLUS_FFT`, optionnaly OR'ed with `FFT_OUTPUT_FORMAT_RAW_PLUS_FFT`.
- `footer` - Describes if a footer is attached to the returned records. Must be an element of the `FFT_FOOTER` enum.
- `reserved` - Reserved for future use. Pass 0.
- `bytesPerOutputRecord` - Returns the number of bytes in each record coming out of the FFT module. This value can be used to know how long the allocated DMA buffers must be.

RETURN_CODE **AlazarFFTSetWindowFunction**(*dsp_module_handle dspHandle*, U32 *samplesPerRecord*, float **realWindowArray*, float **imagWindowArray*)

Sets the window function to use with an on-FPGA FFT module.

Downloads a window function to an AlazarTech digitizer's memory. This window function will be used during all subsequent acquisitions that use the on-FPGA DSP module.

This function should be called before *AlazarFFTSetup()*. It does not have to be called every time an acquisition is done. It can be located in the board configuration section.

Parameters

- `dspHandle` - The handle of the FFT DSP module to set the window function for.
- `samplesPerRecord` - The number of samples in the window function array.
- `realWindowArray` - The real window function array. Passing `NULL` is equivalent to passing an array filled with ones.
- `imagWindowArray` - The imaginary window function array. Passing `NULL` is equivalent to passing an array filled with zeros.

RETURN_CODE **AlazarFreeBufferU16**(HANDLE *handle*, U16 **buffer*)

Frees a buffer allocated with *AlazarAllocBufferU16()*

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `buffer` - Base address of the buffer to free

RETURN_CODE **AlazarFreeBufferU8**(HANDLE *handle*, U8 **buffer*)

Frees a buffer allocated with *AlazarAllocBufferU8()*

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `buffer` - Base address of the buffer to free

RETURN_CODE **AlazarFreeBufferU16Ex**(HANDLE *handle*, U16 **buffer*)
Frees a buffer allocated with *AlazarAllocBufferU16Ex()*

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `buffer` - Base address of the buffer to free

RETURN_CODE **AlazarFreeBufferU8Ex**(HANDLE *handle*, U8 **buffer*)
Frees a buffer allocated with *AlazarAllocBufferU8Ex()*

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `buffer` - Base address of the buffer to free

RETURN_CODE **AlazarForceTrigger**(HANDLE *handle*)
Generate a software trigger event.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle

RETURN_CODE **AlazarForceTriggerEnable**(HANDLE *handle*)
Generate a software trigger enable event.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle

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HANDLE **AlazarGetBoardBySystemHandle**(HANDLE *systemHandle*, U32 *boardId*)

Get a handle to a board in a board system where the board system is specified by a handle to its master board and the board by its identifier within the system.

Return A handle to the specified board if it was found

Return NULL if the master board handle is invalid, or a board with the specified board identifier was not found in the specified board system.

Parameters

- `systemHandle` - Handle to master board
- `boardId` - Board identifier in the board system

HANDLE **AlazarGetBoardBySystemID**(U32 *systemId*, U32 *boardId*)

Get a handle to a board in a board system where the board and system are identified by their ID.

Detailed description

Return A handle to the specified board if it was found.

Return NULL if the board with the specified `systemId` and `boardId` was not found.

Parameters

- `systemId` - The system identifier
- `boardId` - The board identifier

U32 **AlazarGetBoardKind**(HANDLE *handle*)

Get a board model identifier of the board associated with a board handle.

Return A non-zero board model identifier upon success. See BoardTypes for converting the identifier into a board model.

Return Zero upon error.

Parameters

- `handle` - Board handle

RETURN_CODE **AlazarGetBoardRevision**(HANDLE *handle*, U8 **major*, U8 **minor*)

Get the PCB hadware revision level of a digitizer board.

AlazarTech periodically updates the PCB hadware of its digitizers to improve functionality. Many PCIE digitizers can report the PCB hadware revision to software. Note that this function is not supported on PCI digitizer boards.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - The board handle
- `major` - PCB major version number
- `minor` - PCB minor version number

RETURN_CODE **AlazarGetChannelInfo**(HANDLE *handle*, U32 **memorySize*, U8 **bitsPerSample*)

Get the on-board memory in samples per channel, and sample size in bits per sample.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark The memory size information is independant of how many channels the board can acquire on simultaneously. When multiple channels acquire data, they share this amount.

Remark The memory size indication is given for the default packing mode. See documentation about data packing for more information.

Parameters

- `handle` - Board handle.
- `memorySize` - Size of the on-board memory in samples.
- `bitsPerSample` - Bits per sample.

RETURN_CODE **AlazarGetCPLDVersion**(HANDLE *handle*, U8 **major*, U8 **minor*)

Get the CPLD version number of the specified board.

Parameters

- `handle` - Board handle
- `major` - CPLD version number
- `minor` - CPLD version number

RETURN_CODE **AlazarGetDriverVersion**(U8 **major*, U8 **minor*, U8 **revision*)

Get the device driver version of the most recently opened device.

Driver releases are given a version number with the format X.Y.Z where: X is the major release number, Y is the minor release number, and Z is the minor revision number.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

See *AlazarGetSDKVersion()*

See *AlazarGetCPLDVersion()*

Parameters

- `major` - The driver major version number

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- `minor` - The driver minor version number
- `revision` - The driver revision number

RETURN_CODE **AlazarGetMaxRecordsCapable**(HANDLE *handle*, U32 *samplesPerRecord*, U32 **maxRecordsPerCapture*)

Calculate the maximum number of records that can be captured to on-board memory given the requested number of samples per record.

Remark This function is part of the single-port API. It should not be used with AutoDMA API functions.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `samplesPerRecord` - The desired number of samples per record
- `maxRecordsPerCapture` - The maximum number of records per capture possible with the requested value of samples per record.

RETURN_CODE **AlazarGetParameter**(HANDLE *handle*, U8 *channel*, U32 *parameter*, long **retValue*)

Get a device parameter as a signed long value.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `channel` - The channel to control. See *ALAZAR_CHANNELS* for a list of possible values. This parameter only takes unsigned 8-bit values.
- `parameter` - The Parameter to modify. This can be one of *ALAZAR_PARAMETERS*.
- `retValue` - Parameter's value

RETURN_CODE **AlazarGetParameterUL**(HANDLE *handle*, U8 *channel*, U32 *parameter*, U32 **retValue*)

Get a device parameter as an unsigned long value.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle

- `channel` - The channel to control. See *ALAZAR_CHANNELS* for a list of possible values. This parameter only takes unsigned 8-bit values.
- `parameter` - The Parameter to modify. This can be one of *ALAZAR_PARAMETERS*.
- `retValue` - Parameter's value

RETURN_CODE **AlazarGetSDKVersion**(U8 **major*, U8 **minor*, U8 **revision*)

Get the driver library version. This is the version of ATSApi.dll under Windows, or ATSApi.so under Linux.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark Note that the version number returned is that of the driver library file, not the ATS-SDK version number. SDK releases are given a version number with the format X.Y.Z where: X is the major release number, Y is the minor release number, and Z is the minor revision number.

See *AlazarGetCPLDVersion()*

See *AlazarGetDriverVersion()*

Parameters

- `major` - The SDK major version number
- `minor` - The SDK minor version number
- `revision` - The SDK revision number

U32 **AlazarGetStatus**(HANDLE *handle*)

Return a bitmask with board status information.

Return If the function fails, the return value is 0xFFFFFFFF. Upon success, the return value is a bit mask of the following values:

- 1 : At least one trigger timeout occured.
- 2 : At least one channel A sample was out of range during the last acquisition.
- 4 : At least one channel B sample was out of range during the last acquisition.
- 8 : PLL is locked (ATS660 only)

Parameters

- `handle` - Board handle

HANDLE **AlazarGetSystemHandle**(U32 *systemId*)

Return the handle of the master board in the specified board system.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

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Parameters

- `systemId` - System identification number

RETURN_CODE **AlazarGetTriggerAddress**(HANDLE *handle*, U32 *Record*, U32 **TriggerAddress*, U32 **TimeStampHighPart*, U32 **TimeStampLowPart*)

Get the timestamp and trigger address of the trigger event in a record acquired to on-board memory.

The following code fragment demonstrates how to convert the trigger timestamp returned by *AlazarGetTriggerAddress()* from counts to seconds.

```
__int64 timeStamp_cnt;
timeStamp_cnt = ((__int64) timestampHighPart) << 8;
timeStamp_cnt |= timestampLowPart & 0x0ff;
double samplesPerTimestampCount = 2; // board specific constant
double samplesPerSec = 50.e6; // sample rate
double timeStamp_sec = (double) samplesPerTimestampCount *
timeStamp_cnt / samplesPerSec;
```

The sample per timestamp count value depends on the board model. See board-specific information to know which value applies to which board.

Return *ApiError2* (604) if it is called after a dual-port acquisition. This function should be called after a single-port acquisition only.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark This function can be used in single-port acquisitions only.

Parameters

- `handle` - Board handle
- `Record` - Record in acquisition (1-indexed)
- `TriggerAddress` - The trigger address
- `TimeStampHighPart` - The most significant 32-bits of a record timestamp
- `TimeStampLowPart` - The least significant 8-bits of a record timestamp

RETURN_CODE **AlazarGetTriggerTimestamp**(HANDLE *handle*, U32 *Record*, U64 **Timestamp_samples*)

Retrieve the timestamp, in sample clock periods, of a record acquired to on-board memory.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark This function is part of the single-port data acquisition API. It cannot be used to retrieve the timestamp of records acquired using dual-port AutoDMA APIs.

Parameters

- `handle` - Board handle
- `Record` - 1-indexed record in acquisition
- `Timestamp_samples` - Record timestamp, in sample clock periods

U32 **`AlazarGetWhoTriggeredBySystemHandle`**(HANDLE *systemHandle*, U32 *boardId*, U32 *recordNumber*)

Return which event caused a board system to trigger and capture a record to on-board memory.

Remark This function is part of the single-port API. It cannot be used with the dual-port AutoDMA APIs.

Return One of the following values:

- 0 : This board did not cause the system to trigger
- 1 : CH A on this board caused the system to trigger
- 2 : CH B on this board caused the system to trigger
- 3 : EXT TRIG IN on this board caused the system to trigger
- 4 : Both CH A and CH B on this board caused the system to trigger
- 5 : Both CH A and EXT TRIG IN on this board caused the system to trigger
- 6 : Both CH B and EXT TRIG IN on this board caused the system to trigger
- 7 : A trigger timeout on this board caused the system to trigger

Parameters

- `systemHandle` - Handle to a master board in a board system.
- `boardId` - Board identifier of a board in the specified system.
- `recordNumber` - Record in acquisition (1-indexed)

U32 **`AlazarGetWhoTriggeredBySystemID`**(U32 *systemId*, U32 *boardId*, U32 *recordNumber*)

Return which event caused a board system to trigger and capture a record to on-board memory.

Remark This function is part of the single-port API. It cannot be used with the dual-port AutoDMA APIs.

Return One of the following values:

- 0 : This board did not cause the system to trigger
- 1 : CH A on this board caused the system to trigger
- 2 : CH B on this board caused the system to trigger
- 3 : EXT TRIG IN on this board caused the system to trigger

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- 4 : Both CH A and CH B on this board caused the system to trigger
- 5 : Both CH A and EXT TRIG IN on this board caused the system to trigger
- 6 : Both CH B and EXT TRIG IN on this board caused the system to trigger
- 7 : A trigger timeout on this board caused the system to trigger

Parameters

- `systemId` - System indentifier
- `boardId` - Board identifier of a board in the specified system.
- `recordNumber` - Record in acquisition (1-indexed)

RETURN_CODE **AlazarHyperDisp**(HANDLE *handle*, void **buffer*, U32 *bufferSize*, U8 **viewBuffer*, U32 *viewBufferSize*, U32 *numOfPixels*, U32 *option*, U32 *channelSelect*, U32 *record*, long *transferOffset*, U32 **error*)

Enable the on-board FPGA to process records acquired to on-board memory, and transfer the processed data to host memory.

HyperDisp processing enables the on-board FPGA to divide a record acquired to on-board memory into intervals, find the minimum and maximum sample values during each interval, and transfer an array of minimum and maximum sample values to a buffer in host memory. This allows the acquisition of relatively long records to on-board memory, but the transfer of relatively short, processed records to a buffer in host memory.

For example, it would take an ATS860-256M about ~2.5 seconds to transfer a 250,000,000 sample record from on-board memory, across the PCI bus, to a buffer in host memory. With HyperDisp enabled, it would take the on-board FPGA a fraction of a second to process the record and transfer a few hundred samples from on-board memory, across the PCI bus, to a buffer in host memory.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark *AlazarHyperDisp()* is part of the single-port data acquisition API. It cannot be used with the dual-port AutoDMA APIs.

Parameters

- `handle` - Board handle
- `buffer` - Reseved (Set to NULL)
- `bufferSize` - Number of samples to process
- `viewBuffer` - Buffer to receive processed data
- `viewBufferSize` - Size of processed data buffer in bytes
- `numOfPixels` - Number of HyperDisp points
- `option` - Processing mode. Pass 1 to enable HyperDisp processing.

- `channelSelect` - Channel to process
- `record` - Record to process (1-indexed)
- `transferOffset` - The offset, in samples, of first sample to process relative to the trigger position in record.
- `error` - Pointer to value to receive a result code.

RETURN_CODE **AlazarInputControl**(HANDLE *handle*, U8 *channel*, U32 *coupling*, U32 *inputRange*, U32 *impedance*)

Select the input coupling, range, and impedance of a digitizer channel.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle.
- `channel` - The channel to control. See *ALAZAR_CHANNELS* for a list of possible values. This parameter only takes unsigned 8-bit values. To configure channel I and above, see `AlazarInputControlEx`.
- `inputRange` - Specify the input range of the selected channel. See *ALAZAR_INPUT_RANGES* for a list of all existing input ranges. Consult board-specific information to see which input ranges are supported by each board.
- `coupling` - Specifies the coupling of the selected chanel. Must be an element of *ALAZAR_COUPLINGS*
- `impedance` - Specify the input impedance to set for the selected channel. See *ALAZAR_IMPEDANCES* for a list of all existing values. See the board-specific documentation to see impedances supported by various boards.

RETURN_CODE **AlazarInputControlEx**(HANDLE *handle*, U32 *channel*, U32 *couplingId*, U32 *rangeId*, U32 *impedenceId*)

Select the input coupling, range and impedance of a digitizer channel.

This function is the equivalent of *AlazarInputControl()* with a U32-typed parameter to pass the channel. This allows for boards with more than 8 channels to be configured.

U32 **AlazarNumOfSystems**()

Get the total number of board systems detected.

A *board system* is a group of one or more digitizer oards that share clock and trigger signals. A board system may be composed of a single independent board, or a group of two or more digitizer boards connected together with a *SyncBoard*.

Return return type

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RETURN_CODE **AlazarOCTIgnoreBadClock**(HANDLE *handle*, U32 *enable*, double *goodClockDuration_seconds*, double *badClockDuration_seconds*, double **triggerCycleTime_seconds*, double **triggerPulseWidth_seconds*)

Enables or disables the 'OCT ignore bad clock' mechanism.

Parameters

- `handle` - Handle to board
- `enable` - Enables (1) or disables (0) the feature
- `goodClockDuration_seconds` - Good clock duration in seconds
- `badClockDuration_seconds` - Bad clock duration in seconds
- `triggerCycleTime_seconds` - Trigger cycle time measured by the board
- `triggerPulseWidth_seconds` - Trigger pulse width measured by the board

HANDLE **AlazarOpen**(char **boardName*)

Open and initialize a board.

The ATS library manages board handles internally. This function should only be used in applications that are written for single board digitizer systems.

Parameters

- `boardName` - Name of board created by driver. For example "ATS850-0".

RETURN_CODE **AlazarPostAsyncBuffer**(HANDLE *handle*, void **buffer*, U32 *bufferLength_bytes*)

Posts a DMA buffer to a board.

This function adds a DMA buffer to the end of a list of buffers available to be filled by the board. Use *AlazarWaitAsyncBufferComplete()* to determine if the board has received sufficient trigger events to fill this buffer.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark You must call *AlazarBeforeAsyncRead()* before calling *AlazarPostAsyncBuffer()*.

Warning You must call *AlazarAbortAsyncRead()* before your application exits if you have called *AlazarPostAsyncBuffer()* and buffers are pending when your application exits.

Remark The `bufferLength_bytes` parameter must be equal to the product of the number of bytes per record, the number of records per buffer and the number of enabled channels. If record headers are enabled, the number of bytes per record must include the size of the record header (16 bytes).

Parameters

- `handle` - Handle to board

- `buffer` - Pointer to buffer that will eventually receive data from the digitizer board.
- `bufferLength_bytes` - The length of the buffer in bytes.

RETURN_CODE **AlazarQueryCapability**(HANDLE *handle*, U32 *capability*, U32 *reserved*, U32 **retValue*)

Get a device attribute as a unsigned 32-bit integer.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `capability` - The board capability to query. Must be a member of *ALAZAR_CAPABILITIES*.
- `reserved` - Pass 0
- `retValue` - Capability value

U32 **AlazarRead**(HANDLE *handle*, U32 *channelId*, void **buffer*, int *elementSize*, long *record*, long *transferOffset*, U32 *transferLength*)

Read all of part of a record from on-board memory to host memory (RAM).

The record must be less than 2,147,483,648 samples long.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark *AlazarRead()* is part of the single-port API, it cannot be used in a dual-port context.

Remark *AlazarRead()* can transfer segments of a record. This may be useful if a full record is too large to transfer as a single clock, or if only part of a record is of interest.

Remark Use *AlazarReadEx()* To transfer records with more than 2 billion samples.

Parameters

- `handle` - Board handle
- `channelId` - The channel identifier of the record to read.
- `buffer` - Buffer to receive sample data
- `elementSize` - Number of bytes per sample
- `record` - Index of the record to transfer (1-indexed)
- `transferOffset` - The offset, in samples, from the trigger position in the record, of the first sample to transfer.
- `transferLength` - The number of samples to transfer.

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U32 **AlazarReadEx**(HANDLE *handle*, U32 *channelId*, void **buffer*, int *elementSize*, long *record*, INT64 *transferOffset*, U32 *transferLength*)

Read all or part of a record from an acquisition to on-board memory from on-board memory to a buffer in hsot memory. The record may be longer than 2 billion samples.

Use *AlazarRead()* or *AlazarReadEx()* to transfer records with less than 2 billion samples. Use *AlazarReadEx()* to transfer records with more than 2 billion samples.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark *AlazarReadEx()* is part of the single-port data acquisition API. It cannot be used with the dual-port AutoDMA APIs.

Remark *AlazarReadEx()* can transfer segments of a record to on-board memory. This may be useful if a full record is too large to transfer as a single block, or if only part of a record is of interest.

Parameters

- `handle` - Handle to board
- `channelId` - channel identifier of record to read
- `buffer` - Buffer to receive sample data
- `elementSize` - number of bytes per sample
- `record` - record in on-board memory to transfer to buffer (1-indexed).
- `transferOffset` - The offset in samples from the trigger position in the record of the first sample in the record in on-board memory to transfer to the buffer
- `transferLength` - The number of samples to transfer from the record in on-board memory to the buffer.

RETURN_CODE **AlazarResetTimeStamp**(HANDLE *handle*, U32 *option*)

Resets the record timestamp counter.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark This function is not supported by ATS310, ATS330 and ATS850

Parameters

- `handle` - Handle to board
- `option` - Record timestamp reset option. Can be one of *ALAZAR_TIMESTAMP_RESET_OPTIONS*.

RETURN_CODE **AlazarSetADCBackgroundCompensation**(HANDLE *handle*, BOOL *active*)

Activates or deactivates the ADC background compensation.

Remark This feature does not exist on all boards. Please check board-specific information for more details.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Handle to board
- `active` - Determines whether this function activates or deactivates the ADC background compensation.

RETURN_CODE **AlazarSetBWLimit**(HANDLE *handle*, U32 *channel*, U32 *enable*)

Activates the bandwith limiter of an input channel. Not all boards support a bandwidth limiter. See board-specific documentation for more information.

Remark The bandwidth limiter is disabled by default. When enabled, the bandwith is limited to approximatively 20 MHz.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `channel` - The channel identifier. Must be a channel from *ALAZAR_CHANNELS*.
- `enable` - Pass 1 to enable the bandwith limit, or zero otherwise.

RETURN_CODE **AlazarSetCaptureClock**(HANDLE *handle*, U32 *source*, U32 *sampleRateIdOrValue*, U32 *edgeId*, U32 *decimation*)

Configure the sample clock source, edge and decimation.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `source` - Clock source identifiers. Must be a member of `ALAZAR_CLOCK_SOURCES`. See board-specific information for a list of valid values for each board. For external clock types, the identifier to choose may depend on the clock's frequency. See board-specific information for a list of frequency ranges for all clock types.
- `sampleRateIdOrValue` - If the clock source chosen is `INTERNAL_CLOCK`, this value is a member of `ALAZAR_CLOCK_RATES` that defines the internal sample rate to choose. Valid values for each board vary. If the clock source chosen is `EXTERNAL_CLOCK_10_MHZ_REF`, pass the value of the sample clock to generate from the reference in herts. The values that can be generated depend on the board model.

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Otherwise, the clock source is external, pass SAMPLE_RATE_USER_DEF to this parameter.

- edgeId - The external clock edge on which to latch sample rate. Must be a member of ALAZAR_CLOCK_EDGES.
- decimation - Decimation value. May be an integer between 0 and 100000 with the following exceptions. Note that a decimation value of 0 means disable decimation. - If an ATS460/ATS660/ATS860 is configured to use a SLOW_EXTERNAL_CLOCK clock source, the maximum decimation value is 1. - If an ATS9350 is configured to use an EXTERNAL_CLOCK_10MHz_REF clock source, the decimation value must be 1, 2, 4 or any multiple of 5. Note that the sample rate identifier value must be 500000000, and the sample rate will be 500 MHz divided by the decimation value. - If an ATS9360 / ATS9371 / ATS9373 is configured to use an EXTERNAL_CLOCK_10MHz_REF clock source, the maximum decimation value is 1. - If an ATS9850 is configured to use an EXTERNAL_CLOCK_10MHz_REF clock source, the decimation value must be 1, 2, 4 or any multiple of 10. Note that the sample rate identifier value must be 500000000, and the sample rate will be 500 MHz divided by the decimation value. - If an ATS9870 is configured to use an EXTERNAL_CLOCK_10MHz_REF clock source, the decimation value must be 1, 2, 4 or any multiple of 10. Note that the sample rate identifier value must be 1000000000, and the sample rate will be 1 GHz divided by the decimation value.

RETURN_CODE **AlazarSetExternalClockLevel**(HANDLE *handle*, float *level_percent*)

Set the external clock comparator level.

Remark Only the following boards support this feature: ATS460, ATS660, ATS860, ATS9350, ATS9351, ATS9440, ATS9462, ATS9625, ATS9626, ATS9870.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- handle - Board handle
- level_percent - The external clock comparator level, in percent.

RETURN_CODE **AlazarSetExternalTrigger**(HANDLE *handle*, U32 *couplingId*, U32 *rangeId*)

Set the external trigger range and coupling.

Parameters

- handle - Board handle
- couplingId - Specifies the external trigger coupling. See *ALAZAR_COUPLINGS* for existing values. Consult board-specific information to see which values are supported by each board.
- rangeId - Specifies the external trigger range. See *ALAZAR_EXTERNAL_TRIGGER_RANGES* for a list of all existing values. Consult board-specific information to see which values are supported by each board.

RETURN_CODE **AlazarSetLED**(HANDLE *handle*, U32 *state*)
Control the LED on a board's mounting bracket.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `state` - to put the LED in. Must be a member of *ALAZAR_LED*

RETURN_CODE **AlazarSetParameter**(HANDLE *handle*, U8 *channel*, U32 *parameter*, long *value*)
Set a device parameter as a signed long value.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `channel` - The channel to control. See *ALAZAR_CHANNELS* for a list of possible values. This parameter only takes unsigned 8-bit values.
- `parameter` - The Parameter to modify. This can be one of *ALAZAR_PARAMETERS*.
- `value` - Parameter value

RETURN_CODE **AlazarSetParameterUL**(HANDLE *handle*, U8 *channel*, U32 *parameter*, U32 *value*)
Set a device parameter as an unsigned long value.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `channel` - The channel to control. See *ALAZAR_CHANNELS* for a list of possible values. This parameter only takes unsigned 8-bit values.
- `parameter` - The Parameter to modify. This can be one of *ALAZAR_PARAMETERS*.
- `value` - Parameter value

RETURN_CODE **AlazarSetRecordCount**(HANDLE *handle*, U32 *Count*)
Select the number of records to capture to on-board memory.

Return *ApiSuccess* upon success

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Return An error code upon error. See the error code list for more detailed information.

Remark This function is part of the single-port API, and cannot be used in a dual-port context.

Parameters

- `handle` - Board handle
- `Count` - The number of records to acquire to on-board memory during the acquisition.

RETURN_CODE **AlazarSetRecordSize**(HANDLE *handle*, U32 *preTriggerSamples*, U32 *postTriggerSamples*)

Set the number of pre-trigger and post-trigger samples per record.

Remark The number of pre-trigger samples must not exceed the number of samples per record minus 64.

Remark The number of samples per record is the sum of the pre- and post-trigger samples. It must follow requirements specific to each board listed in the board-specific documentation.

Remark The maximum number of records per capture is a function of the board type, the maximum number of samples per channel (SPC), and the current number of samples per record (SPR) :

- ATS850, ATS310, ATS330 : min(SPC / (SPR + 16), 10000)
- ATS460, ATS660, ATS9462 : min(SPC / (SPR + 16), 256000)
- ATS860, ATS9325, ATS935X : min(SPC / (SPR + 32), 256000)
- ATS9850, ATS9870 : min(SPC / (SPR + 64), 256000)

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `preTriggerSamples` - Number of samples before the trigger position in each record.
- `postTriggerSamples` - Number of samples after the trigger position in each record.

RETURN_CODE **AlazarSetTriggerDelay**(HANDLE *handle*, U32 *Delay*)

Set the time, in sample clocks, to wait after receiving a trigger event before capturing a record for the trigger.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle

- `Delay` - Trigger delay in sample clocks. Must be a value between 0 and 9 999 999. It must also be a multiple of a certain value that varies from one board to another. See board-specific information to know which multiplier must be respected.

RETURN_CODE **AlazarSetTriggerOperation**(HANDLE *handle*, U32 *TriggerOperation*, U32 *TriggerEngine1*, U32 *Source1*, U32 *Slope1*, U32 *Level1*, U32 *TriggerEngine2*, U32 *Source2*, U32 *Slope2*, U32 *Level2*)

Configures the trigger system.

Remark The trigger level is specified as an unsigned 8-bit code that represents a fraction of the full scale input voltage of the trigger source: 0 represents the negative limit, 128 represents the 0 level, and 255 represents the positive limit. For example, if the trigger source is CH A, and the CH A input range is ± 800 mV, then 0 represents a –800 mV trigger level, 128 represents a 0 V trigger level, and 255 represents +800 mV trigger level.

Remark If the trigger source is external, the full scale input voltage for the external trigger connector is dictated by the *AlazarSetExternalTrigger()* function.

Remark All PCI Express boards except ATS9462 support only one external trigger level. If both `Source1` and `Source2` are set to TRIG_EXTERNAL, `Level1` is ignored and only `Level2` is used. All other boards support using different values for the two levels.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle
- `TriggerOperation` - Specify how the two independant trigger engines generate a trigger. This can be one of *ALAZAR_TRIGGER_OPERATIONS*
- `TriggerEngine1` - First trigger engine to configure. Can be one of *ALAZAR_TRIGGER_ENGINES*.
- `Source1` - Signal source for the first trigger engine. Can be one of *ALAZAR_TRIGGER_SOURCES*.
- `Slope1` - Sign Direction of the trigger voltage slope that will generate a trigger event for the first engine. Can be one of *ALAZAR_TRIGGER_SLOPES*.
- `Level1` - Select the voltage level that the trigger signal must cross to generate a trigger event.
- `TriggerEngine2` - Second trigger engine to configure. Can be one of *ALAZAR_TRIGGER_ENGINES*.
- `Source2` - Signal source for the second trigger engine. Can be one of *ALAZAR_TRIGGER_SOURCES*.
- `Slope2` - Sign Direction of the trigger voltage slope that will generate a trigger event for the second engine. Can be one of *ALAZAR_TRIGGER_SLOPES*.

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- `Level2` - Select the voltage level that the trigger signal must cross to generate a trigger event.

RETURN_CODE **AlazarSetTriggerOperationForScanning**(HANDLE *handle*, U32 *slopeId*, U32 *level*, U32 *options*)

Configure the trigger engines of a board to use an external trigger input and, optionally, synchronize the start of an acquisition with the next external trigger event after *AlazarStartCapture()* is called.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark *AlazarSetTriggerOperationForScanning()* is intended for scanning applications that supply both external clock and external trigger signals to the digitizer, where the external clock is not suitable to drive the digitizer in between trigger events.

Remark This function configures a board to use trigger operation TRIG_ENGINE_OP_J, and the source of TRIG_ENGINE_J to be TRIG_EXTERNAL. The application must call *AlazarSetExternalTrigger()* to set the full-scale external input range and coupling of the external trigger signal connected to the TRIG IN connector. An application should call *AlazarSetTriggerOperationForScanning()* or *AlazarSetTriggerOperation()*, but not both.

Remark The trigger level is specified as an unsigned 8-bit code that represents a fraction of the full scale input voltage of the external trigger range: 0 represents the negative limit, 128 represents the 0 level, and 255 represents the positive limit.

Remark *AlazarSetTriggerOperationForScanning()* in currently only supported on ATS9462 with FPGA 35.0 or later.

Parameters

- `handle` - Board handle
- `slopeId` - Select the direction of the rate of change of the external trigger signal when it crosses the trigger voltage level that is required to generate a trigger event. Must be an element of *ALAZAR_TRIGGER_SLOPES*.
- `level` - Specify a trigger level code representing the trigger level in volts that an external trigger signal connected must pass through to generate a trigger event. See the Remarks section below.
- `options` - The options parameter may be one of `ALAZAR_STOS_OPTIONS`

RETURN_CODE **AlazarSetTriggerTimeOut**(HANDLE *handle*, U32 *timeout_ticks*)

Set the time to wait for a trigger event before automatically generating a trigger event.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Parameters

- `handle` - Board handle

- `timeout_ticks` - The trigger timeout value in ticks. A tick is 10μs.

RETURN_CODE **AlazarSleepDevice**(HANDLE *handle*, U32 *sleepState*)
Control power to ADC devices.

Parameters

- `handle` - Handle to board
- `sleepState` - Specifies the power state of the ADC converters. This paramter can be one of *ALAZAR_POWER_STATES*.

RETURN_CODE **AlazarStartCapture**(HANDLE *handle*)
Arm a board to start an acquisition.

Return *ApiSuccess* upon success

Return An error code upon error. See the error code list for more detailed information.

Remark Only call on the master board in a master-slave system.

U32 **AlazarTriggered**(HANDLE *handle*)
Determine if a board has triggered during the current acquisition.

Return If the board has received at least one trigger event since the last call to *AlazarStartCapture()*, this function returns 1. Otherwise, it returns 0.

Parameters

- `handle` - Board handle

RETURN_CODE **AlazarWaitAsyncBufferComplete**(HANDLE *handle*, void **buffer*, U32 *timeout_ms*)
This function returns when a board has received sufficient triggers to fill the specified buffer, or when the timeout internal elapses.

Each call to *AlazarPostAsyncBuffer()* adds a buffer to the end of a list fo buffers to be filled by the board. *AlazarWaitAsyncBufferComplete()* expects to wait on the buffer at the head of this list. As a result, you must wait for buffers in the same order than they were posted.

Return If the board receives sufficien ttrigger events to fill this buffer before the timeout interval elapses, the function returns *ApiSuccess*.

Return If the timeout interval elapses before the board receives sufficient trigger events to fill the buffer, the function returns *ApiWaitTimeout*.

Return If the board overflows its on-board memory, the function returns *ApiBufferOverflow*. This happens if the rate at which data is acquired is fater than the rate at which data is being transferred from on-board memory to host memory across the host bus interface.

Return If this buffer was not found in the list of buffers available to be filled by the board, the function returns *ApiBufferNotReady*.

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Return If this buffer is not the buffer at the head of the list of buffers to be filled by the board, this returns *ApiDmaInProgress*.

Return If the function fails for some other reason, it returns an error code that indicates the reason that it failed. See `RETURN_CODE` for more information.

Remark You must call *AlazarBeforeAsyncRead()* and *AlazarPostAsyncBuffer()* before calling *AlazarWaitAsyncBufferComplete()*.

Warning You must call *AlazarAbortAsyncRead()* before your application exits if your have called *AlazarPostAsyncBuffer()* and buffers are pending.

Parameters

- `handle` - Handle to board
- `buffer` - Pointer to a buffer to receive sample data form the digitizer board
- `timeout_ms` - The time to wait for the buffer to be filled, in milliseconds.

When *AlazarWaitAsyncBufferComplete()* returns *ApiSuccess*, the buffer is removed from the list of buffers to be filled by the board.

The arrangement of sample data in each buffer depends on the AutoDMA mode specified in the call to *AlazarBeforeAsyncRead()*.

RETURN_CODE **AlazarWaitNextAsyncBufferComplete**(HANDLE *handle*, void **buffer*, U32 *bytesToCopy*, U32 *timeout_ms*)

This function returns when the board has received sufficient trigger events to fill the buffer, or the timeout interval has elapsed.

To use this function, *AlazarBeforeAsyncRead()* must be called with ADMA_ALLOC_BUFFERS.

You must call *AlazarBeforeAsyncRead()* with the ADMA_GET_PROCESSED_DATA flag before calling *AlazarWaitNextAsyncBufferComplete()*.

Return If the board receives sufficient trigger events to fill the next available buffer before the timeout interval elapses, and the buffer is not the last buffer in the acquisition, the function returns *ApiSuccess*.

Return If the board receives sufficient trigger events to fill the next available buffer before the timeout interval elapses, and the buffer is the last buffer in the acquisition, the function returns *ApiTransferComplete*.

Return If the timeout interval elapses before the board receives sufficient trigger events to fill the next available buffer, the function returns *ApiWaitTimeout*.

Return If the board overflows its on-board memory, the function returns *ApiBufferOverflow*. The board may overflow its on-board memory because the rate at which it is acquiring data is faster than the rate at which the data is being transferred from on-board memory to host memory across the host bus interface (PCI or PCIe). If this is the case, try reducing the sample rate, number of enabled channels, or amount of time spent processing each buffer.

Return If the function fails for some other reason, it returns an error code that indicates the reason that it failed.

Parameters

- `handle` - Handle to board
- `buffer` - Pointer to a buffer to receive sample data from the digitizer board.
- `bytesToCopy` - The number of bytes to copy into the buffer
- `timeout_ms` - The time to wait for the buffer to buffer to be filled, in milliseconds.

To discard buffers, set the bytesToCopy parameter to zero. This will cause *AlazarWaitNextAsyncBufferComplete()* to wait for a buffer to complete, but not copy any data into the application buffer.

To enable disk streaming using high-performance disk I/O functions, call *AlazarCreateStreamFile()* before calling *AlazarWaitNextAsyncBufferComplete()*. For best performance, set the bytesToCopy parameter to zero so that data is streamed to disk without making any intermediate copies in memory.

If *AlazarBeforeAsyncRead()* is called with the ADMA_GET_PROCESSED_DATA flag, AlazarWaitNextAsyncBuferComplete() will process buffers so that the data always appears in NPT format: R1A, R2A, ... RnA, R1B, R2B, ... RnB. This may simply you application, but it comes at the expense of added processing time for each buffer. If *AlazarBeforeAsyncRead()* is not called with the called with the ADMA_GET_PROCESSED_DATA flag set, then arrangement of sample data in a buffer depends on the AutoDMA mode.

Constant Definitions

enum ALAZAR_CAPABILITIES

Capabilities that can be queried through *AlazarQueryCapability()*

Values:

GET_SERIAL_NUMBER = 0x10000024UL
Board's serial number.

GET_FIRST_CAL_DATE = 0x10000025UL
First calibration date.

GET_LATEST_CAL_DATE = 0x10000026UL
Latest calibration date.

GET_LATEST_TEST_DATE = 0x10000027UL
Latest test date.

GET_LATEST_CAL_DATE_MONTH = 0x1000002DUL
Month of latest calibration.

GET_LATEST_CAL_DATE_DAY = 0x1000002EUL
Day of latest calibration.

GET_LATEST_CAL_DATE_YEAR = 0x1000002FUL
Year of latest calibration.

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GET_BOARD_OPTIONS_LOW = 0x10000037UL
Low part of the board options.

GET_BOARD_OPTIONS_HIGH = 0x10000038UL
High part of the board options.

MEMORY_SIZE = 0x1000002AUL
The memory size in samples.

ASOPC_TYPE = 0x1000002CUL
The FPGA signature.

BOARD_TYPE = 0x1000002BUL
The board type as a member of ALAZAR_BOARDTYPES.

GET_PCIE_LINK_SPEED = 0x10000030UL
PCIe link speed in Gb/s.

GET_PCIE_LINK_WIDTH = 0x10000031UL
PCIe link width in lanes.

GET_MAX_PRETRIGGER_SAMPLES = 0x10000046UL
Maximum number of pre-trigger samples.

GET_CPF_DEVICE = 0x10000071UL
User-programmable FPGA device. 1 = SL50, 2 = SE260.

HAS_RECORD_FOOTERS_SUPPORT = 0x10000073UL
Queries if the board supports NPT record footers. Returns 1 if the feature is supported and 0 otherwise

enum ALAZAR_ECC_MODES
ECC Modes.

Values:

ECC_DISABLE = 0

ECC_ENABLE = 1

enum ALAZAR_AUX_INPUT_LEVELS
Auxiliary input levels.

Values:

AUX_INPUT_LOW = 0

AUX_INPUT_HIGH = 1

enum ALAZAR_PACK_MODES
Data pack modes.

Values:

PACK_DEFAULT = 0
Default pack mode of the board.

PACK_8_BITS_PER_SAMPLE = 1
8 bits per sample

PACK_12_BITS_PER_SAMPLE = 2
12 bits per sample

enum ALAZAR_API_TRACE_STATES
API trace states.

Values:

API_ENABLE_TRACE = 1

API_DISABLE_TRACE = 0

enum ALAZAR_PARAMETERS
Parameters suitable to be used with *AlazarSetParameter()* and/or *AlazarGetParameter()*

Values:

SETGET_ASYNC_BUFFSIZE_BYTES = 0x10000039UL
The size of API-allocated DMA buffers in bytes.

SETGET_ASYNC_BUFFCOUNT = 0x10000040UL
The number of API-allocated DMA buffers.

GET_ASYNC_BUFFERS_PENDING = 0x10000050UL
DMA buffers currently posted to the board.

GET_ASYNC_BUFFERS_PENDING_FULL = 0x10000051UL
DMA buffers waiting to be processed by the application

GET_ASYNC_BUFFERS_PENDING_EMPTY = 0x10000052UL
DMA buffers waiting to be filled by the board.

SET_DATA_FORMAT = 0x10000041UL
0 if the data format is unsigned, and 1 otherwise

GET_DATA_FORMAT = 0x10000042UL
0 if the data format is unsigned, and 1 otherwise

GET_SAMPLES_PER_TIMESTAMP_CLOCK = 0x10000044UL
Number of samples per timestamp clock.

GET_RECORDS_CAPTURED = 0x10000045UL
Records captured since the start of the acquisition (single-port) or buffer (dual-port)

ECC_MODE = 0x10000048UL
ECC mode. Member of *ALAZAR_ECC_MODES*.

GET_AUX_INPUT_LEVEL = 0x10000049UL
Read the TTL level of the AUX connector. Member of *ALAZAR_AUX_INPUT_LEVELS*

GET_CHANNELS_PER_BOARD = 0x10000070UL
Number of analog channels supported by this digitizer.

GET_FPGA_TEMPERATURE = 0x10000080UL
Current FPGA temperature in degrees Celcius. Only supported by PCIe digitizers.

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PACK_MODE = 0x10000072UL
Get/Set the pack mode as a member of *ALAZAR_PACK_MODES*

SET_SINGLE_CHANNEL_MODE = 0x10000043UL
Reserve all the on-board memory to the channel passed as argument. Single-port only.

API_FLAGS = 0x10000090UL
State of the API logging as a member of *ALAZAR_API_TRACE_STATES*

enum ALAZAR_ADC_MODES
Analog to digital converter modes.

Values:

ADC_MODE_DEFAULT = 0
Default ADC mode.

ADC_MODE_DES = 1
Dual-edge sampling mode.

enum ALAZAR_PARAMETERS_UL
Parameters suitable to be used with *AlazarSetParameterUL()* and/or *AlazarGetParameterUL()*

Values:

SET_ADC_MODE = 0x10000047UL
Set the ADC mode as a member of *ALAZAR_ADC_MODES*.

SET_BUFFERS_PER_TRIGGER_ENABLE = 0x10000097UL
Configures the number of DMA buffers acquired after each trigger enable event. The default value is 1.

Remark To set the number of buffers per trigger enable, this must be called after *AlazarBeforeAsyncRead()* but before *AlazarStartCapture()*, which means that *AlazarBeforeAsyncRead()* must be called with ADMA_EXTERNAL_STARTCAPTURE

Remark This parameter is reset in between acquisitions.

GET_POWER_MONITOR_STATUS = 0x10000098UL
Queries the status of the power monitor on the board.

```
The value returned is zero if there is no problem. If it is not zero,
please send the value returned to AlazarTech's technical support.
```

enum ALAZAR_BOARD_OPTIONS_LOW
AlazarTech board options. Lower 32-bits.

Values:

OPTION_STREAMING_DMA = (1UL << 0)

OPTION_EXTERNAL_CLOCK = (1UL << 1)

OPTION_DUAL_PORT_MEMORY = (1UL << 2)

OPTION_180MHZ_OSCILLATOR = (1UL << 3)

OPTION_LVTTL_EXT_CLOCK = (1UL << 4)

OPTION_SW_SPI = (1UL << 5)

OPTION_ALT_INPUT_RANGES = (1UL << 6)

OPTION_VARIABLE_RATE_10MHZ_PLL = (1UL << 7)

OPTION_MULTI_FREQ_VCO = (1UL << 7)

OPTION_2GHZ_ADC = (1UL << 8)

OPTION_DUAL_EDGE_SAMPLING = (1UL << 9)

OPTION_DCLK_PHASE = (1UL << 10)

OPTION_WIDEBAND = (1UL << 11)

enum ALAZAR_BOARD_OPTIONS_HIGH
AlazarTech board options. Higher 32-bits.

Values:

OPTION_OEM_FPGA = (1ULL << 15)

enum ALAZAR_SAMPLE_RATES
Sample rate identifiers.

Values:

SAMPLE_RATE_1KSPS = 0X00000001UL

SAMPLE_RATE_2KSPS = 0X00000002UL

SAMPLE_RATE_5KSPS = 0X00000004UL

SAMPLE_RATE_10KSPS = 0X00000008UL

SAMPLE_RATE_20KSPS = 0X0000000AUL

SAMPLE_RATE_50KSPS = 0X0000000CUL

SAMPLE_RATE_100KSPS = 0X0000000EUL

SAMPLE_RATE_200KSPS = 0X00000010UL

SAMPLE_RATE_500KSPS = 0X00000012UL

SAMPLE_RATE_1MSPS = 0X00000014UL

SAMPLE_RATE_2MSPS = 0X00000018UL

SAMPLE_RATE_5MSPS = 0X0000001AUL

SAMPLE_RATE_10MSPS = 0X0000001CUL

SAMPLE_RATE_20MSPS = 0X0000001EUL

SAMPLE_RATE_25MSPS = 0X00000021UL

SAMPLE_RATE_50MSPS = 0X00000022UL

SAMPLE_RATE_100MSPS = 0X00000024UL

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SAMPLE_RATE_125MSPS = 0x00000025UL

SAMPLE_RATE_160MSPS = 0x00000026UL

SAMPLE_RATE_180MSPS = 0x00000027UL

SAMPLE_RATE_200MSPS = 0X00000028UL

SAMPLE_RATE_250MSPS = 0X0000002BUL

SAMPLE_RATE_400MSPS = 0X0000002DUL

SAMPLE_RATE_500MSPS = 0X00000030UL

SAMPLE_RATE_800MSPS = 0X00000032UL

SAMPLE_RATE_1000MSPS = 0x00000035UL

SAMPLE_RATE_1GSPS = SAMPLE_RATE_1000MSPS

SAMPLE_RATE_1200MSPS = 0x00000037UL

SAMPLE_RATE_1500MSPS = 0x0000003AUL

SAMPLE_RATE_1600MSPS = 0x0000003BUL

SAMPLE_RATE_1800MSPS = 0x0000003DUL

SAMPLE_RATE_2000MSPS = 0x0000003FUL

SAMPLE_RATE_2GSPS = SAMPLE_RATE_2000MSPS

SAMPLE_RATE_2400MSPS = 0x0000006AUL

SAMPLE_RATE_3000MSPS = 0x00000075UL

SAMPLE_RATE_3GSPS = SAMPLE_RATE_3000MSPS

SAMPLE_RATE_3600MSPS = 0x0000007BUL

SAMPLE_RATE_4000MSPS = 0x00000080UL

SAMPLE_RATE_4GSPS = SAMPLE_RATE_4000MSPS

SAMPLE_RATE_300MSPS = 0x00000090UL

SAMPLE_RATE_350MSPS = 0x00000094UL

SAMPLE_RATE_370MSPS = 0x00000096UL

SAMPLE_RATE_USER_DEF = 0x00000040UL
User-defined sample rate. Used with external clock.

enum ALAZAR_IMPEDANCES
Impedance indentifiers.

Values:

IMPEDANCE_1M_OHM = 0x00000001UL

IMPEDANCE_50_OHM = 0x00000002UL

IMPEDANCE_75_OHM = 0x00000004UL

IMPEDANCE_300_OHM = 0x00000008UL

enum ALAZAR_CLOCK_SOURCES
Clock source identifiers.

Values:

INTERNAL_CLOCK = 0x00000001UL

EXTERNAL_CLOCK = 0x00000002UL

FAST_EXTERNAL_CLOCK = 0x00000002UL

MEDIUM_EXTERNAL_CLOCK = 0x00000003UL

SLOW_EXTERNAL_CLOCK = 0x00000004UL

EXTERNAL_CLOCK_AC = 0x00000005UL

EXTERNAL_CLOCK_DC = 0x00000006UL

EXTERNAL_CLOCK_10MHZ_REF = 0x00000007UL

INTERNAL_CLOCK_10MHZ_REF = 0x00000008

EXTERNAL_CLOCK_10MHZ_PXI = 0x0000000A

INTERNAL_CLOCK_DIV_4 = 0x0000000F

INTERNAL_CLOCK_DIV_5 = 0x00000010

MASTER_CLOCK = 0x00000011

INTERNAL_CLOCK_SET_VCO = 0x00000012

enum ALAZAR_CLOCK_EDGES
Clock edge identifiers.

Values:

CLOCK_EDGE_RISING = 0x00000000UL

CLOCK_EDGE_FALLING = 0x00000001UL

enum ALAZAR_INPUT_RANGES
Input range identifiers.

Values:

INPUT_RANGE_PM_20_MV = 0x00000001UL

INPUT_RANGE_PM_40_MV = 0x00000002UL

INPUT_RANGE_PM_50_MV = 0x00000003UL

INPUT_RANGE_PM_80_MV = 0x00000004UL

INPUT_RANGE_PM_100_MV = 0x00000005UL

INPUT_RANGE_PM_200_MV = 0x00000006UL

INPUT_RANGE_PM_400_MV = 0x00000007UL

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INPUT_RANGE_PM_500_MV = 0x00000008UL

INPUT_RANGE_PM_800_MV = 0x00000009UL

INPUT_RANGE_PM_1_V = 0x0000000AUL

INPUT_RANGE_PM_2_V = 0x0000000BUL

INPUT_RANGE_PM_4_V = 0x0000000CUL

INPUT_RANGE_PM_5_V = 0x0000000DUL

INPUT_RANGE_PM_8_V = 0x0000000EUL

INPUT_RANGE_PM_10_V = 0x0000000FUL

INPUT_RANGE_PM_20_V = 0x00000010UL

INPUT_RANGE_PM_40_V = 0x00000011UL

INPUT_RANGE_PM_16_V = 0x00000012UL

INPUT_RANGE_HIFI = 0x00000020UL

INPUT_RANGE_PM_1_V_25 = 0x00000021UL

INPUT_RANGE_PM_2_V_5 = 0x00000025UL

INPUT_RANGE_PM_125_MV = 0x00000028UL

INPUT_RANGE_PM_250_MV = 0x00000030UL

enum ALAZAR_COUPLINGS
Coupling identifiers.

Values:

AC_COUPLING = 0x00000001UL
AC coupling.

DC_COUPLING = 0x00000002UL
DC coupling.

enum ALAZAR_TRIGGER_ENGINES
Trigger engine identifiers.

Values:

TRIG_ENGINE_J = 0x00000000UL
The J trigger engine.

TRIG_ENGINE_K = 0x00000001UL
The K trigger engine.

enum ALAZAR_TRIGGER_OPERATIONS
Trigger operation identifiers.

Values:

TRIG_ENGINE_OP_J = 0x00000000UL
The board triggers when a trigger event is detected by trigger engine J. Events detected by engine K are ignored.

TRIG_ENGINE_OP_K = 0x00000001UL
The board triggers when a trigger event is detected by trigger engine K. Events detected by engine J are ignored.

TRIG_ENGINE_OP_J_OR_K = 0x00000002UL
The board triggers when a trigger event is detected by any of the J and K trigger engines.

TRIG_ENGINE_OP_J_AND_K = 0x00000003UL
This value is deprecated. It cannot be used.

TRIG_ENGINE_OP_J_XOR_K = 0x00000004UL
This value is deprecated. It cannot be used.

TRIG_ENGINE_OP_J_AND_NOT_K = 0x00000005UL
This value is deprecated. It cannot be used.

TRIG_ENGINE_OP_NOT_J_AND_K = 0x00000006UL
This value is deprecated. It cannot be used.

enum ALAZAR_TRIGGER_SOURCES
Trigger sources.

Values:

TRIG_CHAN_A = 0x00000000UL

TRIG_CHAN_B = 0x00000001UL

TRIG_EXTERNAL = 0x00000002UL

TRIG_DISABLE = 0x00000003UL

TRIG_CHAN_C = 0x00000004UL

TRIG_CHAN_D = 0x00000005UL

TRIG_CHAN_E = 0x00000006UL

TRIG_CHAN_F = 0x00000007UL

TRIG_CHAN_G = 0x00000008UL

TRIG_CHAN_H = 0x00000009UL

TRIG_CHAN_I = 0x0000000AUL

TRIG_CHAN_J = 0x0000000BUL

TRIG_CHAN_K = 0x0000000CUL

TRIG_CHAN_L = 0x0000000DUL

TRIG_CHAN_M = 0x0000000EUL

TRIG_CHAN_N = 0x0000000FUL

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TRIG_CHAN_O = 0x00000010UL

TRIG_CHAN_P = 0x00000011UL

TRIG_PXI_STAR = 0x00000100UL

enum ALAZAR_TRIGGER_SLOPES

Trigger slope identifiers.

These identifiers selects whether rising or falling edges of the trigger source signal are detected as trigger events.

Values:

TRIGGER_SLOPE_POSITIVE = 0x00000001UL

The trigger engine detects a trigger event when sample values from the trigger source rise above a specified level.

TRIGGER_SLOPE_NEGATIVE = 0x00000002UL

The trigger engine detects a trigger event when sample values from the trigger source fall below a specified level.

enum ALAZAR_CHANNELS

Channel identifiers.

Values:

CHANNEL_ALL = 0x00000000

CHANNEL_A = 0x00000001

CHANNEL_B = 0x00000002

CHANNEL_C = 0x00000004

CHANNEL_D = 0x00000008

CHANNEL_E = 0x00000010

CHANNEL_F = 0x00000020

CHANNEL_G = 0x00000040

CHANNEL_H = 0x00000080

CHANNEL_I = 0x00000100

CHANNEL_J = 0x00000200

CHANNEL_K = 0x00000400

CHANNEL_L = 0x00000800

CHANNEL_M = 0x00001000

CHANNEL_N = 0x00002000

CHANNEL_O = 0x00004000

CHANNEL_P = 0x00008000

enum ALAZAR_MASTER_SLAVE_CONFIGURATION
Master/Slave configuration.

Values:

BOARD_IS_INDEPENDENT = 0x00000000UL

BOARD_IS_MASTER = 0x00000001UL

BOARD_IS_SLAVE = 0x00000002UL

BOARD_IS_LAST_SLAVE = 0x00000003UL

enum ALAZAR_LED
LED state identifiers.

Values:

LED_OFF = 0x00000000UL

LED_ON = 0x00000001UL

enum ALAZAR_EXTERNAL_TRIGGER_RANGES
External trigger range identifiers.

Values:

ETR_5V = 0x00000000UL

ETR_1V = 0x00000001UL

ETR_TTL = 0x00000002UL

ETR_2V5 = 0x00000003UL

enum ALAZAR_POWER_STATES
Power states.

Values:

POWER_OFF = 0x00000000UL

POWER_ON = 0x00000001UL

enum ALAZAR_SOFTWARE_EVENTS_CONTROL
Software events control. See AlazarEvents()

Values:

SW_EVENTS_OFF = 0x00000000UL

SW_EVENTS_ON = 0x00000001UL

enum ALAZAR_TIMESTAMP_RESET_OPTIONS
Timestamp reset options. See *AlazarResetTimeStamp()*

Values:

TIMESTAMP_RESET_FIRSTTIME_ONLY = 0x00000000UL

TIMESTAMP_RESET_ALWAYS = 0x00000001UL

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enum ALAZAR_AUX_IO_MODES

Alazar AUX I/O identifiers.

Values:

AUX_OUT_TRIGGER = 0U

Outputs a signal that is high whenever data is being acquired to on-board memory, and low otherwise. The `parameter` argument of *AlazarConfigureAuxIO()* is ignored in this mode.

AUX_IN_TRIGGER_ENABLE = 1U

Uses the edge of a pulse to the AUX I/O connector as an AutoDMA *trigger enable* signal. Please note that this is different from a standard *trigger* signal. In this mode, the `parameter` argument of *AlazarConfigureAuxIO()* can takes an element of *ALAZAR_TRIGGER_SLOPES*, which defines on which edge of the input signal a trigger enable event is generated.

AUX_OUT_PACER = 2U

Output the sample clock divided by the value passed to the `parameter` argument of *AlazarConfigureAuxIO()*. Please note that the divided must be greater than 2.

AUX_OUT_SERIAL_DATA = 14U

Use the AUX I/O connector as a general purpose digital output. The `paramter` argument of *AlazarConfigureAuxIO()* specifies the TTL output level. 0 means TTL low level, whereas 1 means TTL high level.

AUX_IN_AUXILIARY = 13U

Configure the AUX connector as a digital input. Call *AlazarGetParameter()* with *GET_AUX_INPUT_LEVEL* to read the digital input level.

enum ALAZAR_STOS_OPTIONS

Options for AlazarSetExternalTriggerOperationForScanning()

Values:

STOS_OPTION_DEFER_START_CAPTURE = 1

enum ALAZAR_SAMPLE_SKIPPING_MODES

Data skipping modes. See *AlazarConfigureSampleSkipping()*

Values:

SSM_DISABLE = 0

SSM_ENABLE = 1

enum ALAZAR_COPROCESSOR_DOWNLOAD_OPTIONS

Coprocessor download options.

Values:

CPF_OPTION_DMA_DOWNLOAD = 1

enum ALAZAR_LSB

Least significant bit identifiers.

Values:

LSB_DEFAULT = 0

LSB_EXT_TRIG = 1

LSB_AUX_IN_1 = 3

LSB_AUX_IN_2 = 2

enum ALAZAR_BOARD_PERSONALITIES
AlazarTech board personalities.

Values:

BOARD_PERSONALITY_DEFAULT = 0

BOARD_PERSONALITY_8KFFT = 1

Structures

typedef struct *_ALAZAR_HEADER* **ALAZAR_HEADER**
Traditional Record Header Typedef.

struct _ALAZAR_HEADER
Traditional Record Header.

Public Members

struct *_HEADER0* **hdr0**
Substructure 0.

struct *_HEADER1* **hdr1**
Substructure 1.

struct *_HEADER2* **hdr2**
Substructure 2.

struct *_HEADER3* **hdr3**
Substructure 3.

struct _HEADER0
Traditional Record Header Substructure 1.

Public Members

unsigned int **SerialNumber**
18-bit serial number of this board as a signed integer

unsigned int **SystemNumber**
4-bit system identifier number for this board

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unsigned int **WhichChannel**
1-bit input channel of this header. 0 is channel A, 1 is channel B

unsigned int **BoardNumber**
4-bit board identifier number of this board

unsigned int **SampleResolution**
3-bit reserved field

unsigned int **DataFormat**
2-bit reserved field

struct _HEADER1
Traditional Record Header Substructure 1.

Public Members

unsigned int **RecordNumber**
24-bit index of record in the acquisition

unsigned int **BoardType**
8-bit board type identifier. See BoardTypes for a list of existing board

struct _HEADER2
Traditional Record Header Substructure 2.

Public Members

unsigned int **TimeStampLowPart**
Lower 32 bits of 40-bit record timestamp.

struct _HEADER3
Traditional Record Header Substructure 3.

Public Members

unsigned int **TimeStampHighPart**
8-bit field containing the upper part of the 40-bit record timestamp

unsigned int **ClockSource**
2-bit clock source identifier. See *ALAZAR_CLOCK_SOURCES*

unsigned int **ClockEdge**
1-bit clock edge identifier. See *ALAZAR_CLOCK_EDGES*

unsigned int **SampleRate**
7-bit sample rate identifier. See *ALAZAR_SAMPLE_RATES*

unsigned int **InputRange**
5-bit input range identifier. See *ALAZAR_INPUT_RANGES*

unsigned int **InputCoupling**
2-bit input coupling identifier. See *ALAZAR_COUPLINGS*

unsigned int **InputImpedence**
2-bit input impedance identifier. See *ALAZAR_IMPEDANCES*

unsigned int **ExternalTriggered**
1-bit field set if and only if TRIG IN on this board caused the board to

unsigned int **ChannelBTriggered**
capture this record.

1-bit field set if and only if CH B on this board caused the board to

unsigned int **ChannelATriggered**
capture this record.

1-bit field set if and only if CH A on this board caused the board to

unsigned int **TimeOutOccurred**
capture this record.

1-bit field set if and only if a timeout on a trigger engine on this

unsigned int **ThisChannelTriggered**
board caused it to capture this record.

1-bit field set if and only if the channel specified by

Return Codes

enum RETURN_CODE
API functions return codes. Failure is *ApiSuccess*.

Values:

ApiSuccess = API_RETURN_CODE_STARTS
512 - The operation completed without error

ApiFailed
513 - The operation failed

ApiAccessDenied
514

ApiDmaChannelUnavailable
515

ApiDmaChannelInvalid
516

ApiDmaChannelTypeError
517

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ApiDmaInProgress
518

ApiDmaDone
519

ApiDmaPaused
520

ApiDmaNotPaused
521

ApiDmaCommandInvalid
522

ApiDmaManReady
523

ApiDmaManNotReady
524

ApiDmaInvalidChannelPriority
525

ApiDmaManCorrupted
526

ApiDmaInvalidElementIndex
527

ApiDmaNoMoreElements
528

ApiDmaSglInvalid
529

ApiDmaSglQueueFull
530

ApiNullParam
531

ApiInvalidBusIndex
532

ApiUnsupportedFunction
533

ApiInvalidPciSpace
534

ApiInvalidIopSpace
535

ApiInvalidSize
536

ApiInvalidAddress
537

ApiInvalidAccessType
538

ApiInvalidIndex
539

ApiMuNotReady
540

ApiMuFifoEmpty
541

ApiMuFifoFull
542

ApiInvalidRegister
543

ApiDoorbellClearFailed
544

ApiInvalidUserPin
545

ApiInvalidUserState
546

ApiEepromNotPresent
547

ApiEepromTypeNotSupported
548

ApiEepromBlank
549

ApiConfigAccessFailed
550

ApiInvalidDeviceInfo
551

ApiNoActiveDriver
552

ApiInsufficientResources
553

ApiObjectAlreadyAllocated
554

ApiAlreadyInitialized
555

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ApiNotInitialized
556

ApiBadConfigRegEndianMode
557

ApiInvalidPowerState
558

ApiPowerDown
559

ApiFlybyNotSupported
560

ApiNotSupportThisChannel
561

ApiNoAction
562

ApiHSNotSupported
563

ApiVPDNotSupported
564

ApiVpdNotEnabled
565

ApiNoMoreCap
566

ApiInvalidOffset
567

ApiBadPinDirection
568

ApiPciTimeout
569

ApiDmaChannelClosed
570

ApiDmaChannelError
571

ApiInvalidHandle
572

ApiBufferNotReady
573

ApiInvalidData
574

ApiDoNothing
575

ApiDmaSglBuildFailed
576

ApiPMNotSupported
577

ApiInvalidDriverVersion
578

ApiWaitTimeout
579 - The operation did not finish during the timeout interval. try the operation again, or abort the acquisition.

ApiWaitCanceled
580

ApiBufferTooSmall
581

ApiBufferOverflow
582 - The board overflowed its internal (on-board) memory.

ApiInvalidBuffer
583

ApiInvalidRecordsPerBuffer
584

ApiDmaPending
585 - An asynchronous I/O operation was successfully started on the board. It will be completed when sufficient trigger events are supplied to the board to fill the buffer.

ApiLockAndProbePagesFailed
586

ApiWaitAbandoned
587

ApiWaitFailed
588

ApiTransferComplete
589 - This buffer is the last in the current acquisition

ApiPllNotLocked
590 - The on-board PLL circuit could not lock. If the acquisition used an internal sample clock, this might be a symptom of a hardware problem; contact AlazarTech. If the acquisition used an external 10 MHz PLL signal, please make sure that the signal is fed in properly.

ApiNotSupportedInDualChannelMode
591 - The requested acquisition is not possible with two channels. This can be due to

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the sample rate being too fast for DES boards, or to the number of samples per record being too large.

ApiNotSupportedInQuadChannelMode
591 - The requested acquisition is not possible with four channels. This can be due to the sample rate being too fast for DES boards, or to the number of samples per record being too large.

ApiFileIoError
593 - A file read or write error occured.

ApiInvalidClockFrequency
594 - The requested ADC clock frequency is not supported.

ApiInvalidSkipTable
595

ApiInvalidDspModule
596

ApiDESOnlySupportedInSingleChannelMode
597

ApiInconsistentChannel
598

ApiDspFiniteRecordsPerAcquisition
599

ApiNotEnoughNptFooters
600

ApiInvalidNptFooter
601

ApiOCTIgnoreBadClockNotSupported
602 - OCT ignore bad clock is not supported

ApiError1
603 - The requested number of records in a single-port acquisition exceeds the maximum supported by the digitizer. Use dual-ported AutoDMA to acquire more records per acquisition.

ApiError2
604 - The requested number of records in a single-port acquisition exceeds the maximum supported by the digitizer.

ApiOCTNoTriggerDetected
605 - No trigger is detected as part of the OCT ignore bad clock feature.

ApiOCTTriggerTooFast
606 - Trigger detected is too fast for the OCT ignore bad clock feature.

ApiNetworkError
607 - There was an isse related to network. Make sure that the network connection and settings are correct.

ApiFftSizeTooLarge
608 - On-FPGA FFT cannot support FFT that large. Try reducing the FFT size, or querying the maximum FFT size with *AlazarDSPGetInfo()*

ApiGPUError
609 - CUDA returned an error. See log for more information

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CHAPTER

SIX

BOARD-SPECIFIC INFORMATION

Supported impedances and input ranges

ATS310/50Ω, ATS330/50Ω, ATS9120/50Ω ±40mV, ±50mV, ±80mV, ±100mV, ±200mV, ±400mV, ±500mV, ±800mV, ±1V, ±2V, ±4V

ATS310/1MΩ, ATS330/1MΩ ±40mV, ±50mV, ±80mV, ±100mV, ±200mV, ±400mV, ±500mV, ±800mV, ±1V, ±2V, ±4V, ±5V, ±8V, ±10V

ATS460/50Ω ±20mV, ±40mV, ±50mV, ±80mV, ±100mV, ±200mV, ±400mV, ±500mV, ±800mV, ±1V, ±2V, ±4V

ATS460/1MΩ ±20mV, ±40mV, ±50mV, ±80mV, ±100mV, ±200mV, ±400mV, ±500mV, ±800mV, ±1V, ±2V, ±4V, ±5V, ±8V, ±10V

ATS660/50Ω, ATS9462/50Ω ±200mV, ±400mV, ±800mV, ±2V, ±4V

ATS660/1MΩ, ATS9462/1MΩ ±200mV, ±400mV, ±800mV, ±2V, ±4V, ±8V, ±16V

ATS850/50Ω ±40mV, ±50mV, ±80mV, ±100mV, ±200mV, ±400mV, ±500mV, ±800mV, ±1V, ±2V, ±4V

ATS850/1MΩ ±20mV, ±40mV, ±50mV, ±80mV, ±100mV, ±200mV, ±400mV, ±500mV, ±800mV, ±1V, ±2V, ±4V, ±5V, ±8V, ±10V

ATS860/50Ω ±20mV, ±40mV, ±50mV, ±80mV, ±100mV, ±200mV, ±400mV, ±500mV, ±800mV, ±1V, ±2V, ±4V

ATS860/1MΩ ±20mV, ±40mV, ±50mV, ±80mV, ±100mV, ±200mV, ±400mV, ±500mV, ±800mV, ±1V, ±2V, ±4V, ±5V, ±8V, ±10V

ATS9325/50Ω, ATS9350/50Ω, ATS9850/50Ω, ATS9870/50Ω, AXI9870/50Ω ±40mV, ±100mV, ±200mV, ±400mV, ±1V, ±2V, ±4V

ATS9351/50Ω, ATS9360/50Ω, ATS9370/50Ω, ATS9371/50Ω, ATS9373/50Ω ±400mV

ATS9625/50Ω, ATS9626/50Ω ±1.25V

ATS9440/50Ω ±100mV, ±200mV, ±400mV, ±1V, ±2V, ±4V

ATS9416/50Ω ±1V

Samples per record alignment requirements

Board type	Min. record size	Pretrig. alignment	Buffer alignment	NPT Buffer align.
ATS310, ATS330	256	4	16	N/S
ATS460, ATS660	128	16	16	32
ATS850	256	4	16	N/S
ATS860	256	32	32	64
ATS9350, ATS9351	256	32	32	32
ATS9120	256	32	32	32
ATS9360, ATS9370	256	128	128	128
ATS9371, ATS9373	256	128	128	128
ATS9416	256	128	128	128
ATS9440, ATS9462	256	32	32	32
ATS9625, ATS9626	256	32	32	32
ATS9870, AXI9870	256	64	64	64

Samples per timestamp and trigger delay alignment

Numbers in this table correspond to:

- The ratio between timestamp units and sample clocks in traditional record headers.
- The trigger delay value alignment requirement

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	Active Channels				
Board	1 ch.	2 ch.	4 ch.	8 ch.	16 ch.
ATS310	2	1			
ATS330	2	1			
ATS460	2	1			
ATS660	2	1			
ATS850	2	1			
ATS860	4	2	1		
ATS9120	8	4			
ATS9350	8	4			
ATS9351	8	4			
ATS9360	16	8	4	2	1
ATS9370	16	8	4	2	1
ATS9371	16	8	4	2	1
ATS9373	16	8	4	2	1
ATS9416	16	8	4	2	1
ATS9440	4	2	1		
ATS9462	2	1			
ATS9625	2	1			
ATS9626	2	1			
ATS9870	16	8			
AXI9870	16	8			

Possible input channel configurations

	Channels per board		
Channels	2	4	
A	✓	✓	✓
B	✓	✓	✓
A + B	✓	✓	✓
C		✓	✓
A + C		✓	
B + C		✓	
D		✓	✓
A + D		✓	
B + D		✓	
C + D		✓	
A +..+ D		✓	✓
E			✓
F			✓
G			✓
H			✓
A +..+ H			✓
I			✓
J			✓
K			✓
L			✓
M			✓
N			✓
O			✓
P			✓
A +..+ P			✓

Supported sample rates

ATS310 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s

ATS330 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 25MS/s, 50MS/s

ATS460, ATS660 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 125MS/s

ATS850 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 25MS/s, 50MS/s

ATS860 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 25MS/s, 50MS/s, 100MS/s, 125MS/s, 250MS/s

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ATS9350, ATS9351 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 125MS/s, 250MS/s, 500MS/s

ATS9360 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 200MS/s, 500MS/s, 800MS/s, 1000MS/s, 1200MS/s, 1500MS/s, 1800MS/s

ATS9373 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 200MS/s, 500MS/s, 800MS/s, 1000MS/s

ATS9373 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 200MS/s, 500MS/s, 800MS/s, 1000MS/s, 1200MS/s, 1500MS/s, 2000MS/s, 2400MS/s, 3000MS/s, 3600MS/s, 4000MS/s

ATS9416 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s

ATS9440 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 125MS/s

ATS9462 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 125MS/s, 160MS/s, 180MS/s

ATS9625, ATS9626 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 125MS/s, 250MS/s

ATS9870, AXI9870 1kS/s, 2kS/s, 5kS/s, 10kS/s, 20kS/s, 50kS/s, 100kS/s, 200kS/s, 500kS/s, 1MS/s, 2MS/s, 5MS/s, 10MS/s, 20MS/s, 50MS/s, 100MS/s, 250MS/s, 500MS/s, 1000MS/s

Miscellaneous features support

Bandwidth limit ATS460, ATS660, ATS9462, ATS9870

AC input coupling

ATS310, ATS330, ATS460, ATS660, ATS850, ATS860, ATS9350, ATs9440, ATS9462, ATS9870, AXI9870

DC input coupling All boards except ATS9625

8-bit data packing ATS9360, ATS9371, ATS9373, ATS9440

12-bit data packing ATS9360, ATS9371, ATS9373

Configure LSB ATS9440

External trigger level support

Board	1 V	2.5 V	5 V	TTL
ATS310		✓		✓
ATS330		✓		✓
ATS460	✓		✓	
ATS660	✓		✓	
ATS850	✓		✓	
ATS860	✓		✓	
ATS9350			✓	✓
ATS9351			✓	✓
ATS9360		✓		✓
ATS9371		✓		✓
ATS9373		✓		✓
ATS9416				✓
ATS9440			✓	✓
ATS9462	✓		✓	
ATS9625				✓
ATS9626				✓
ATS9870			✓	
AXI9870			✓	

Supported clock types

#INTERNAL_CLOCK

ATS310, ATS330, ATS460, ATS660, ATS850, ATS860, ATS9350, ATS9351, ATS9360, ATS9371, ATS9373, ATS9416, ATS9440, ATS9462, ATS9625, ATS9626, ATS9870, AXI9870

#FAST_EXTERNAL_CLOCK ATS310, ATS330, ATS460, ATS850, ATS860, ATS9360, ATS9371, ATS9373, ATS9416, ATS9440

#MEDIUM_EXTERNAL_CLOCK ATS460

#SLOW_EXTERNAL_CLOCK ATS460, ATS660, ATS860, ATS9350, ATS9351, ATS9440, ATS9462, ATS9870, AXI9870

#EXTERNAL_CLOCK_AC ATS660, ATS9350, ATS9351, ATS9462, ATS9625, ATS9626, ATS9870, AXI9870

#EXTERNAL_CLOCK_DC ATS660, ATS9462

#EXTERNAL_CLOCK_10_MHZ_REF

ATS660, ATS9350, ATS9351, ATS9360, ATS9371, ATS9373, ATS9416, ATS9440, ATS9462, ATS9625, ATS9626, ATS9870, AXI9870

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Frequency limits for external clock types

Values are in MHz unles noted otherwise

	Fast		Medium		Slow		AC		DC	
	low	high	low	high	low	high	low	high	low	high
ATS310	0	20								
ATS330	0	50								
ATS460	80	125	10	80	0	10				
ATS660					0	10	1k	125	1k	125
ATS850										
ATS860	20	250			0	250				
ATS9350					0	20	1	500		
ATS9351					0	20	1	500		
ATS9360							300	1800		
ATS9371							300	1000		
ATS9373							300	2000		
ATS9416							5	100		
ATS9440	1	125			0	20				
ATS9462					0	10	1	180	1	180
ATS9625							50	250		
ATS9626							50	250		
ATS9870					0	60	200	1000		
AXI9870					0	60	200	1000		

Valid frequencies in PLL mode

ATS660	100-130 MHz in 1 MHZ steps
ATS9350 / ATS9351	500 MHz
ATS9360	300-1800 MHz in 1 MHz steps
ATS9371	300-1000 MHz in 1 MHz steps
ATS9373 in non-DES mode	300-2000 MHz in 1 MHz steps
ATS9373 in DES mode	500-2000 MHz in 1 MHz steps
ATS9416	5-100 MHz in 1 MHz steps
ATS9440	125 MHz or 100 MHz
ATS9462	150-180 MHz in 1 MHz steps
ATS9625 / ATS9626	250 MHz
ATS9870 / AXI9870	1 GHz

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