ATS9416 User Manual

14 Bit, 16 Channel, 100 MS/s
Waveform Digitizer for PCI Express Gen 2 Bus

Written for Hardware Version 1.3
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Information required when contacting AlazarTech for technical support:

Owned by: _____

Serial Number: _____

Purchase Date: _____

Purchased From: _____

Software Driver Version: _____

SDK Version: _____

ATS-GPU Version: _____

ATS-GMA Version: _____

AlazarDSO® Version: _____

Operating System: _____

Important Information

Warranty

The ATS9416 is warranted against defects in materials and workmanship for a period of one year from the date of shipment, as evidenced by receipts or other documentation. AlazarTech, Inc. will, at its option, repair or replace equipment that proves to be defective during the warranty period. This warranty includes parts and labor.

The media on which you receive AlazarTech, Inc. software are warranted not to fail to execute programming instructions, due to defects in materials and workmanship, for a period of 90 days from date of shipment, as evidenced by receipts or other documentation. AlazarTech, Inc. will, at its option, repair or replace software media that do not execute programming instructions if AlazarTech, Inc. receives notice of such defects during the warranty period. AlazarTech, Inc. does not warrant that the operation of the software shall be uninterrupted or error free.

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Compliance

FCC/Canadian Interference-Causing Equipment Standard (ICES-003) Compliance*

Determining FCC Class

The Federal Communications Commission (FCC) has rules to protect wireless communications from interference. The FCC places digital electronics into two classes. These classes are known as Class A (for use in industrial-commercial locations only) or Class B (for use in residential or commercial locations). Depending on where it is operated, this product could be subject to restrictions in the FCC rules. (In Canada, the department of Innovation, Science and Economic Development (ISED), regulates wireless interference in much the same way.)

Digital electronics emit weak signals during normal operation that can affect radio, television, or other wireless products. By examining the product you purchased, you can determine the FCC Class and therefore which of the two FCC/ISED Warnings apply in the following sections. (Some products may not be labeled at all for FCC; if so, the reader should then assume these are Class A devices.)

FCC Class A products only display a simple warning statement of one paragraph in length regarding interference and undesired operation. Most of our products are FCC Class A. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

FCC Class B products display either a FCC ID code, starting with the letters **EXN**, or the FCC Class B compliance mark.

Consult the FCC website http://www.fcc.gov for more information.

FCC/ISED Warnings

This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual and the CE Mark Declaration of Conformity**, may cause interference to radio and television reception. Classification requirements are the same for the Federal Communications Commission (FCC) and Innovation, Science and Economic Development (ISED) Canada.

Changes or modifications not expressly approved by AlazarTech Inc. could void the user's authority to operate the equipment under the FCC/ISED Rules.

Class A
Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Innovation, Science and Economic Development Canada

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Standard (ICES-003). Cet appareil numérique de la classe A respecte toutes les exigences du Règlement sur le matériel brouilleur du Canada.

Compliance to EU Directives

Readers in the European Union (EU) must refer to the Manufacturer's Declaration of Conformity (DoC) for information** pertaining to the CE Mark compliance scheme. The Manufacturer includes a DoC for most every hardware product except for those bought for OEMs, if also available from an original manufacturer that also markets in the EU, or where compliance is not required as for electrically benign apparatus or cables.

To obtain the DoC for this product, click **Declaration of Conformity** at www.alazartech.com/support/documents.htm. This web page lists all DoCs by product family. Select the appropriate product to download or read the DoC.

* Certain exemptions may apply in the USA, see FCC Rules §15.103 **Exempted devices**, and §15.105(c). Also available in sections of CFR 47.

** The CE Mark Declaration of Conformity will contain important supplementary information and instructions for the user or installer.

Environmental Compliance

Alazar Technologies Inc., hereby certifies that this product is RoHS compliant, as defined by Directive 2015/863/EU (RoHS 3) of the European Parliament and of the Council of 31 March 2015 on the restriction of the use of certain hazardous substances in electrical and electronic equipment. All manufacturing has been done using RoHS-compliant components and lead-free soldering.

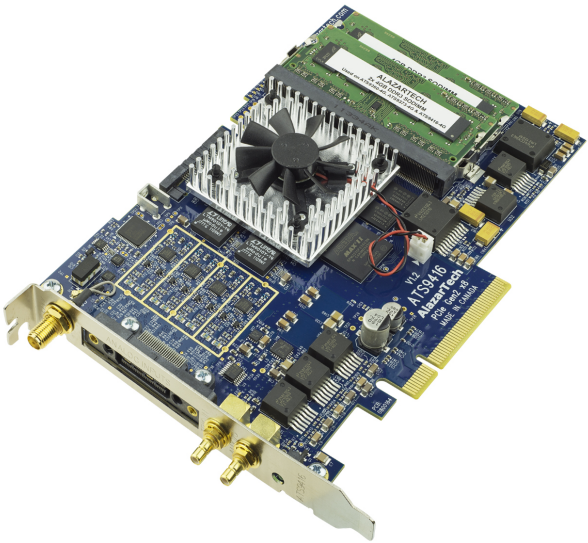
Table of Contents

Change Log

This is the first edition of this manual

Chapter 1
Introduction

This chapter describes the ATS9416 and lists additional equipment.



About Your ATS9416

Thank you for your purchase of an ATS9416. This PCI Express (PCIe Gen2 x8) based waveform digitizer has the following features:

- Sixteen (16) 14-bit resolution analog input channels
- Real-time sampling rate of 100 MS/s to 100 KS/s
- Uses on-board SO-DIMM RAM as a very deep FIFO
- Streaming of acquired data to PC host memory at 3.5 GB/s (exact rate is motherboard dependent)
- 65 MHz analog input bandwidth. Optional upgrade to 100 MHz available.
- Half length PCI Express (8 lane) card
- External trigger input channel
- DC coupling and fixed 50 Ω input impedance for analog inputs
- Pre-trigger and Post-Trigger Capture with Multiple Record capability
- NIST- or CNRC-traceable calibration
- Dual DMA engines for best latency protection against Windows® and Linux® operating systems
- Fully asynchronous software driver for fastest DMA with least CPU overhead

All ATS9416 digitizers follow industry-standard Plug and Play specifications on all platforms and offer seamless integration with compliant systems.

Detailed specifications of the ATS9416 digitizers are listed in Appendix A, Specifications.

ATS9416 Export Control Classification

According to the Export Controls Division of Government of Canada, ATS9416 is currently not controlled for export from Canada. Its export control classification is N8, which is equivalent to ECCN EAR99. ATS9416 can be shipped freely outside of Canada, with the exception of countries listed on the Area Control List and Sanctions List.

Furthermore, if the end-use of ATS9416, in part or in its entirety, is related to the development or deployment of weapons of mass destruction, AlazarTech is obliged to apply for an export permit. This process may cause significant delays.

Acquiring Data with Your ATS9416

You can acquire data either programmatically by writing an application for your ATS9416 or interactively with the AlazarDSO software.

If you want to integrate the ATS9416 in your test and measurement or embedded OEM application, you can program the digitizer using C/C++, Python, MATLAB® or LabVIEW® for Windows or Linux operating systems.

- Windows operating systems supported are Windows 10, Windows 8, Windows 7, Windows Server 2013, Windows Server 2010, and Windows Server 2008 R2. Both 32 bit and 64 bit Windows operating systems are supported.
- AlazarTech offers ATS9416 binary drivers for most of the popular linux distributions, such as CentOS, Ubuntu, etc.

  Users can download the binary driver for their specific distribution by choosing from the available drivers here:

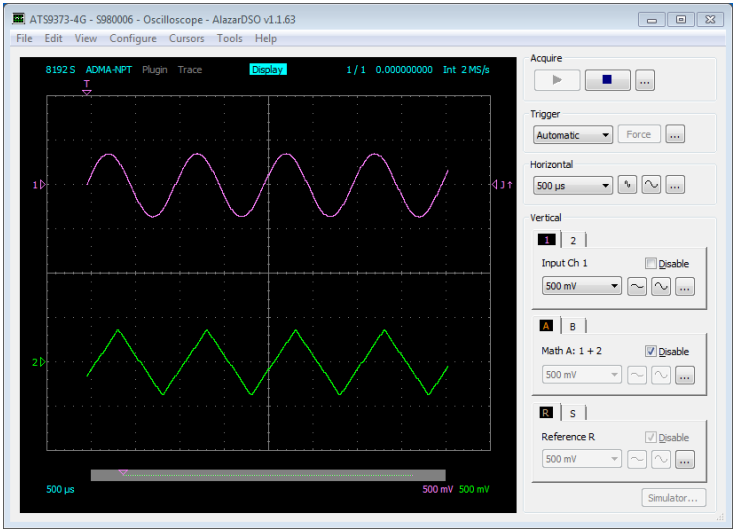
  ftp://release@ftp.alazartech.com/outgoing/linux

  Only 64 bit Linux operating systems are supported.
- Other Linux distributions may also be supported on a case by case basis. Please contact support@alazartech.com for more details. You must include the full output of *uname -a* command from your target Linux system in your email.
- The AlazarTech engineering team may be able to generate an appropriate driver for a nominal fee, if applicable

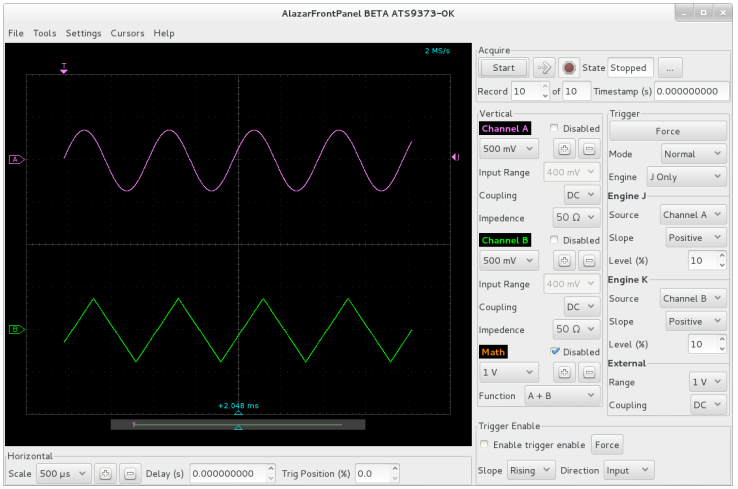
For using a programming language to acquire data from your ATS9416, you must purchase the ATS-SDK package.

Interactively Controlling your ATS9416

The AlazarDSO oscilloscope emulation software for Windows allows you to interactively control your ATS9416 as you would a desktop oscilloscope.



Under Linux, an equivalent application named Alazar Front Panel is available.



Note that Alazar Front Panel has a limited feature set.

ATS-SDK API

The ATS-SDK API is used for programming the ATS9416 in C/C++, C#, LabVIEW, MATLAB and Python. It provides the exact same API that is used for writing AlazarDSO software. To help you get started, ATS-SDK comes with examples you can use or modify.

The ATS-SDK contains the necessary files to develop applications both under Windows and Linux.

ATS-GPU

The ATS-GPU library provides a framework to allow real-time processing of data from AlazarTech PCIe digitizers on a CUDA®-enabled GPU. Using pinned buffers, ATS-GPU can move data at up to 3.5 GB/s for ATS9416. To help you get started, ATS-GPU-BASE comes with an example of a user application that performs very simple signal processing (data inversion) you can use or modify.

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

ATS-GMA

The ATS-GMA library allows True DMA of data from AlazarTech PCIe digitizers to AMD Radeon™ Pro GPU cards at up to 3.5 GB/s for ATS9416, with latency as low as 100 µs. ATS-GMA does not use any host memory buffers for temporary storage. To help you get started, ATS-GMA-BASE comes with an example of a user application that performs very simple signal processing (data inversion) that you can use or modify. ATS-GMA is for OpenCL™-based development.

ATS-GMA-OCT is the optional OCT Signal Processing library for ATS−GMA. It provides out-of-the-box OCT imaging with floating point FFT routines that have been optimized to provide the maximum number of FFTs per second. Kernel code running on the GPU can do zero-padding, apply a windowing function, do a floating point FFT, calculate the amplitude and convert the result to a log scale. It is also possible to output phase information.

Optional Upgrades

AlazarTech offers the following upgrades and accessories for use with your ATS9416 digitizer:

- ATS9416: External Clock Upgrade (5 MHz to 100 MHz)
- ATS9416: Wideband Input Upgrade
- SyncBoard-9416 (2x, 4x, 2x-W, 3x-W, or 4x-W) for creating a multi-board Master/Slave system
- ATS9416: QSS-BNC16 Cable 36 inches
- ATS9416: QSS-QSS Cable 36 inches
- ATS9416: Breakout Board + QSS-QSS Cable

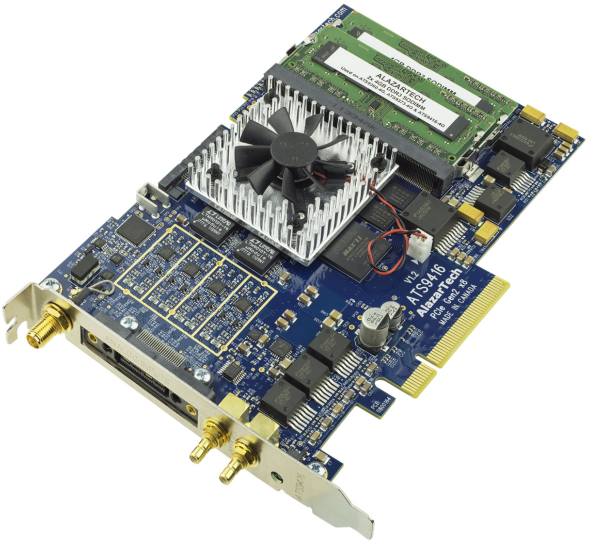
Chapter 2 - Installation and Configuration

This chapter describes how to unpack, install, and configure your ATS9416.

What You Need to Get Started

To set up and use your ATS9416, you will need the following:

- One or more ATS9416 digitizers

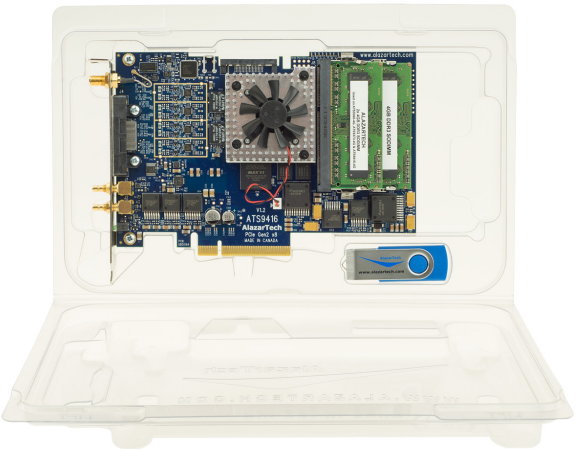


- ATS9416 Installation Software on USB Disk
  (or downloaded software from
  www.alazartech.com/Support/Downloads)

Unpacking

Your digitizer is shipped in an antistatic clamshell package to prevent electrostatic damage to the digitizer. Electrostatic discharge can damage several components on the digitizer. To avoid such damage in handling the digitizer, take the following precautions:

- Ground yourself via a grounding strap or by holding a grounded object.
- Touch the antistatic package to a metal part of your computer chassis before removing the digitizer from the package.
- Remove the digitizer from the package and inspect the digitizer for loose components or any other sign of damage. Notify AlazarTech if the digitizer appears damaged in any way. Do *not* install a damaged digitizer into your computer.
- *Never* touch the exposed pins of the connectors.



Installing the ATS9416

There are four main steps involved in installation:

1. Physically install the digitizer(s) and SyncBoard, if any, in your computer.
2. Install ATS9416 software driver
3. Install AlazarDSO software that allows you to setup the hardware, acquire signals and view and archive them
4. Optionally, install:
    a. The ATS-SDK software development kit, which enables you to programmatically control the ATS9416
    b. The ATS-GPU library, which enables you to perform real-time processing of data from the ATS9416 on a CUDA compatible GPU
    c. The ATS-GMA library, which enables you to DMA data from the ATS9416 on an AMD Radeon Pro GPU card for OpenCL-based development

The following paragraphs will guide you through this process in a step-by-step manner.

1. Physically install the digitizer in your computer

Identify an unused PCI Express slot on your motherboard. As per PCI Express specification, the 8-lane ATS9416 card is compatible with any 8-lane or 16-lane connector on the motherboard. Make sure that your computer is powered off before you attempt to insert the ATS9416 digitizer in one of the free PCI Express slots. For best noise performance, leave as much room as possible between your ATS9416 and other hardware. Always screw the digitizer bracket to the chassis in order to create a stable and robust connection to chassis ground. In the absence of such a connection, ATS9416 is not guaranteed to operate within the specifications listed elsewhere in this manual.

⚠ Some motherboards may have a 16-lane connector, but only one or four of the lanes is connected to the motherboard chipset. Motherboard manufacturers refer to this as “Mechanically 16-lane, electrically 1 lane”. ATS9416 is fully compatible with such motherboards, but the data throughput across PCI Express bus will be limited by the number of lanes.

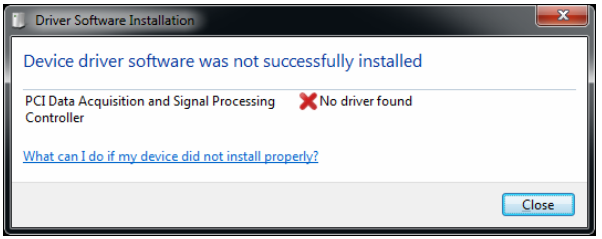
2. Install ATS9416 software driver

Linux users: skip to *Installing the ATS9416 in a Linux System*.

The following instructions guide you through the process of installing the ATS9416 in a computer running Windows 10, 8, 7, Windows Server 2013, Windows Server 2010, or Windows Server 2008 R2 operating systems.
Note that the images of the dialog boxes shown below were taken from a Windows 7 computer. Computers running other versions of Windows may have slightly different dialog boxes.

When you first boot up the computer, the plug-n-play Windows operating system will detect the presence of a new PCI card and will attempt to install the device driver if found on the computer.

a) If the ATS9416 device driver is not found, Windows will display the following dialog box

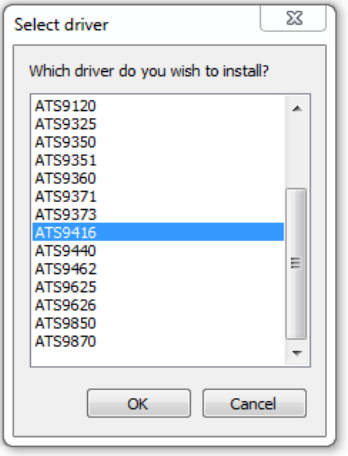


Click **Close**.

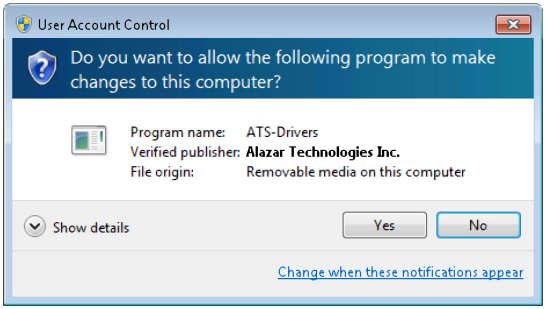
b) Insert the installation disk that is supplied on a USB flash drive. If It does not auto-run, manually run the Autorun.exe program on the USB flash drive. The following splash schreen will be displayed.

Click **Install Driver**.

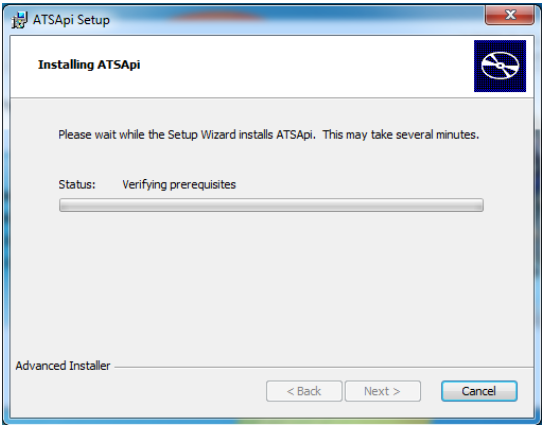
c) The following screen will appear. Select ATS9416 and click OK



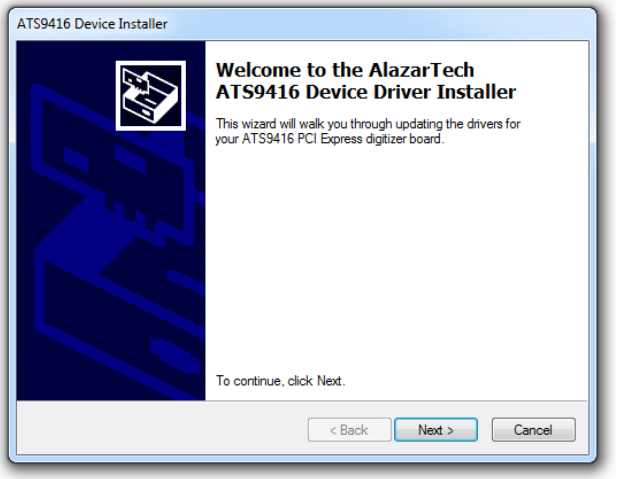
d) The **User Account Control** pop-up window will show up asking for installation permissions.
Click **YES** to continue installation.



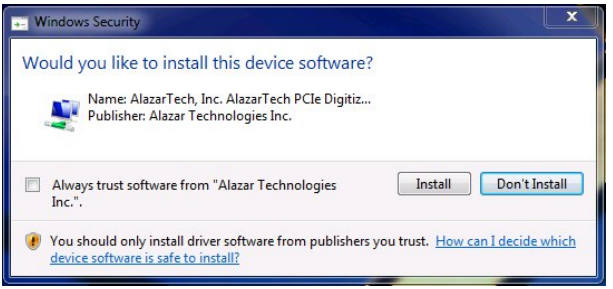
e) Windows will install the ATSApi library.



f) Windows will display the Welcome to the AlazarTech **ATS9416 Device Driver Installer**.



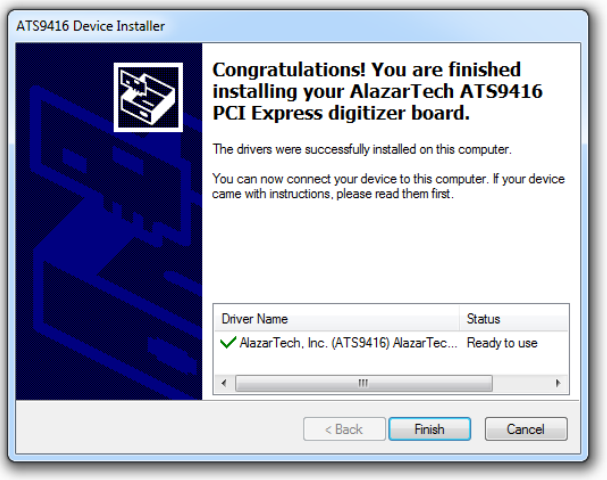
g) Depending on the settings of your Windows user account, you may see a 'Windows Security' screen. Press install, after optionaly checking 'Always trust software from Alazar Technologies Inc.'



Note: If you have Windows 10 v.1607 or later, you cannot install AlazarTech driver versions older than 6.0.0. This is normal behavior. This limitation is due to Microsoft's driver code signing policy change, which now requires a SHA-2 code signing certificate

h) The **ATS9416 Device Installer** box will display the installation progress of the driver files.

Congratulations! The following final screen will confirm that the driver has been successfully installed.



Now your ATS9416 is fully installed and is ready to use.

3. Install AlazarDSO software that allows you to setup the hardware, acquire signals and view and archive them

If you are installing from the USB flash drive shipped with the ATS9416 digitizer, run the Autorun.exe:

- Click on Install AlazarDSO
- Follow the instructions on the screen.

If you are installing AlazarDSO after having downloaded the installation file from AlazarTech web site:

- Download AlazarDSO installation file from www.alazartech.com/support/downloads.htm
- Unzip the file downloaded in the previous step.
- Browse to the folder that contains the unzipped file, AlazarDsoSetup.exe
- Run this executable file and follow the instructions on the screen.

4. Optionally, install the ATS-SDK, ATS-GPU, and ATS-GMA software

Insert the ATS-SDK CD, ATS-GPU CD, or ATS-GMA CD. Software installation will start automatically.

If, for any reason, installation does not start automatically:

- For ATS-SDK, run the ATS-SDK-Setup-7.x.x.exe.
- For ATS-GPU, run the ATS-GPU-3.5.x-win64.exe, then run ATS-SDK-Setup-7.x.x.exe. ATS-SDK is required for ATS-GPU. If you already have ATS-SDK installed on your system, please install the latest ATS-SDK included with your ATS-GPU.
- For ATS-GMA, run the ATS-GMA-4.0.x-win64.exe, then run ATS-SDK-Setup-7.x.x.exe. ATS-SDK is required for ATS-GMA. If you already have ATS-SDK installed on your system, please install the latest ATS-SDK included with your ATS-GMA

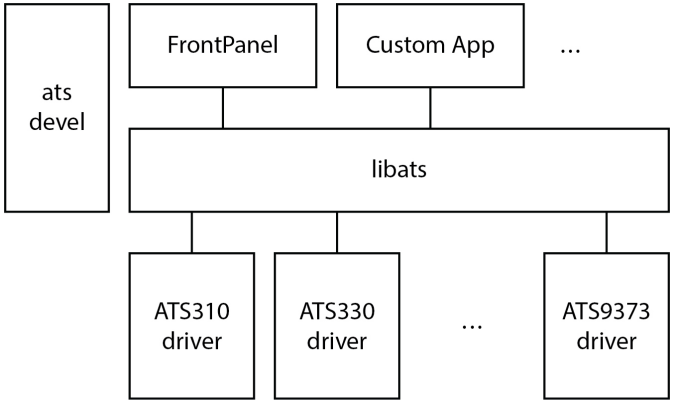
Follow the instructions on the screen.

Note that you must have already installed the ATS9416 drivers for any of the sample programs included with the ATS-SDK, ATS-GPU or ATS-GMA to work properly.

In order to receive the 1 year of support and maintenance included with your ATS-SDK, ATS-GPU, and ATS-GMA, use the serial number provided on the CD envelope(s) and register your product(s) at: http://www.alazartech.com/UserHome?tab=2.

Installing the ATS9416 in a Linux System

To get the latest version of all AlazarTech Linux Packages, please go to: ftp://release@ftp.alazartech.com/Outgoing/Linux



The AlazarTech software components used to communicate with digitizer boards and make acquisitions are divided into several packages:

- **libats**: The shared library that allows user programs to communicate with the board drivers.
- **alazar-front-panel**: A GTK-based virtual oscilloscope application that allows users to get started using the boards without developping their own software.
- **driver packages**: These packages each contain the driver for one of AlazarTech's products. Please note that, contrary to other packages, driver packages are dependent on kernel versions. As such, they are stored in directories named after the kernels they were compiled against. Please make sure to check your kernel version with “uname -a" and only install the driver package that matches your kernel version. If the driver for your specific kernel version is not available on our FTP site, please contact us.

The exact name on disk of a given package file depends on the computer architecture it is built for, the linux distribution used and the actual software version. For example, the driver for ATS9350 version 5.7.0-1 built for the “x86_64” architecture on CentOS is contained in the “ATS9350-5.7.0-1.x86_64.rpm” file.

Installation Instructions

AlazarTech packages can be installed using the standard tools of Linux distributions, e.g. yum/dnf on CentOS/RHEL and Fedora, and apt/aptitude on Debian/Ubuntu. For more information, refer to the documentation of your Linux distribution.

The ATS-SDK product contains an extra software package, called **ats-devel,** for your Linux distribution containing the following components:

1. A programmer's guide for the boards
2. Header files for C/C++ programming, and library wrappers for other programming languages
3. Code samples that demonstrate typical acquisition configurations

Note: The **ats-devel** package is not architecture specific.
A "noarch" text replaces the usual x86₆₄ or i386 field.

On development machines, AlazarTech recommends to install all the packages provided with the boards. On the other hand, in a production environment, the "ats-devel" and "alazar-front-panel" packages are optional. It is enough to install the "libats" package in addition to user-developped applications and the drivers corresponding to the boards used to get a working system.

To install an ATS9416 on your Linux system, follow the next steps:

1. Connect one or several ATS9416 in your computer
2. Start your computer, and install all the software packages for your ATS9416.
3. If you purchased the optional ATS-GPU library, you should have received the software package for your Linux distribution. Contact support@alazartech.com if you have not received the appropriate software package.

Note: If you already have installed different AlazarTech products in your computer, only the driver package will be new. Be sure to use the latest version of all packages though, as for example older libraries may not be compatible with all the features of recent drivers.

Installation Troubleshooting

If you are experiencing difficulties using AlazarTech digitizers on your Linux system, please ensure that the following packages are all installed:

- alazar-front-panel
- libats
- driver package for your board (with the right kernel version)

If these packages are installed, but the AlazarFrontPanel application does not detect your board, please run the following command at a prompt:

```
$ lsmod | grep ATS
```

If this command shows no output, the driver for your board did not start. To know more, run the following command:

```
$ /usr/local/AlazarTech/bin/ATS9373.rc start
```

In the output of this command, if you see a "version mismatch" error, it indicates that the kernel version you are running does not correspond to that with which the driver package was built.

If there is a "Required key not available" message in the output, it indicates that the driver will not load because of a signature issue. On kernels where the EFI_SECURE_BOOT_SIG_ENFORCE config is enabled, third-party drivers cannot load if UEFI Secure Boot is active. The simplest solution is to disable secure boot in the UEFI BIOS settings.

Updating ATS9416 Driver

From time to time, AlazarTech updates the device drivers for its products. These updates may be required for product enhancements or for bug fixes.

This section of the manual takes you through the steps required to update the device driver for the ATS9416 PCI Express waveform digitizer.

In other words, this section shows you how to install a newer version of the driver, when you already have a previous version of the driver installed on your machine.

1. Download the latest driver from AlazarTech's web site: www.alazartech.com/support/downloads.htm
2. ⚠ Unzip the downloaded file to a local folder
3. Run the resulting installation file (*.exe extension). For example, the installation file for driver version 6.00.01 is called **ATS9416_Driver_V6.0.1.exe**, and follow the instructions.

Please note:

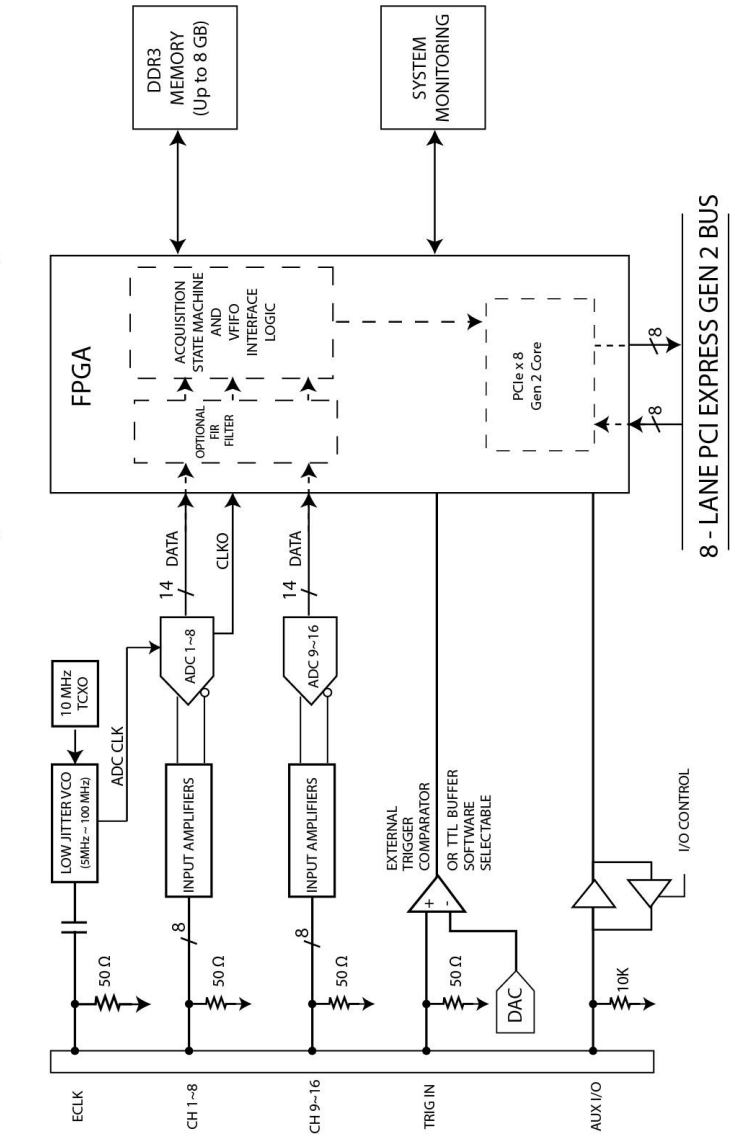
AlazarTech recommends that you register your ATS9416 in order to receive notifications of new driver releases. Take note of your serial number and go to www.alazartech.com/userhome.

You must be logged into your *My AlazarTech* account in order to register a product. If you do not have an account, sign-up for one here: www.alazartech.com/Regstart

Chapter 3
Hardware Overview

This chapter includes an overview of the ATS9416, explains the operation of each functional unit making up your ATS9416, and describes the signal connections.

Following is a high-level block diagram of ATS9416.


ATS9416 BLOCK DIAGRAM (WITH FIR PROCESSING)
DDR3 MEMORY (Up to 8 GB)
SYSTEM MONITORING
FPGA
ACQUISITION STATE MACHINE AND VFIFO INTERFACE LOGIC
OPTIONAL FIR FILTER
PCIe x 8 Gen 2 Core
8 - LANE PCI EXPRESS GEN 2 BUS
10 MHz TCXO
LOW JITTER VCO (5MHz ~ 100 MHz)
ADC CLK
ADC 1~8
ADC 9~16
14 DATA
CLKO
INPUT AMPLIFIERS
50 Ω
EXTERNAL TRIGGER COMPARATOR
OR TTL BUFFER SOFTWARE SELECTABLE
DAC
10K
I/O CONTROL
ECLK
CH 1~8
CH 9~16
TRIG IN
AUX I/O

Physical Overview

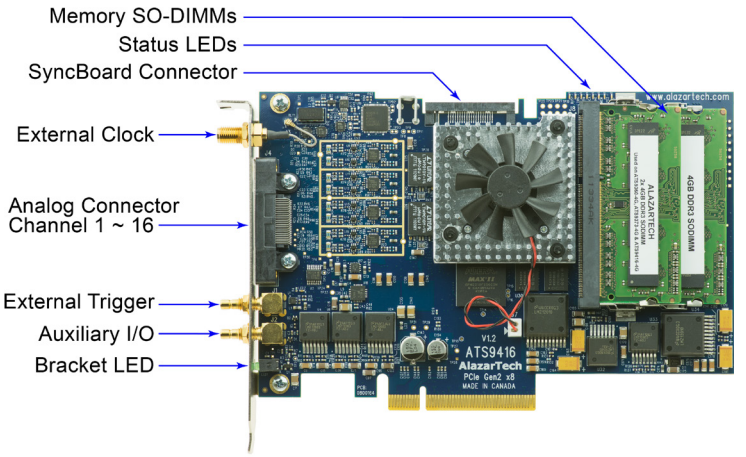


Figure 1 - ATS9416 Overview

ATS9416 has 1 SMA, 1 SAMTEC QSS-025-01-L-D-RA-MTI, and 2 SMB connectors:

- ECLK: The external clock input (SMA)
- CH 1 to CH 16 (SAMTEC QSS-025-01-L-D-RA-MTI)
- TRIG IN: The external trigger input (SMB)
- AUX I/O: An auxiliary input/output connector (SMB)

It also has a bracket LED that can be software controlled, and is used for identification.

In addition, ATS9416 has a special connector on the edge of the PCB, used for connection to a SyncBoard for master/slave operation.

ATS9416 has two memory SO-DIMM connectors on the back of the PCB.

Lastly, ATS9416 has various status LEDs on the edge of the PCB that can be used for debugging.

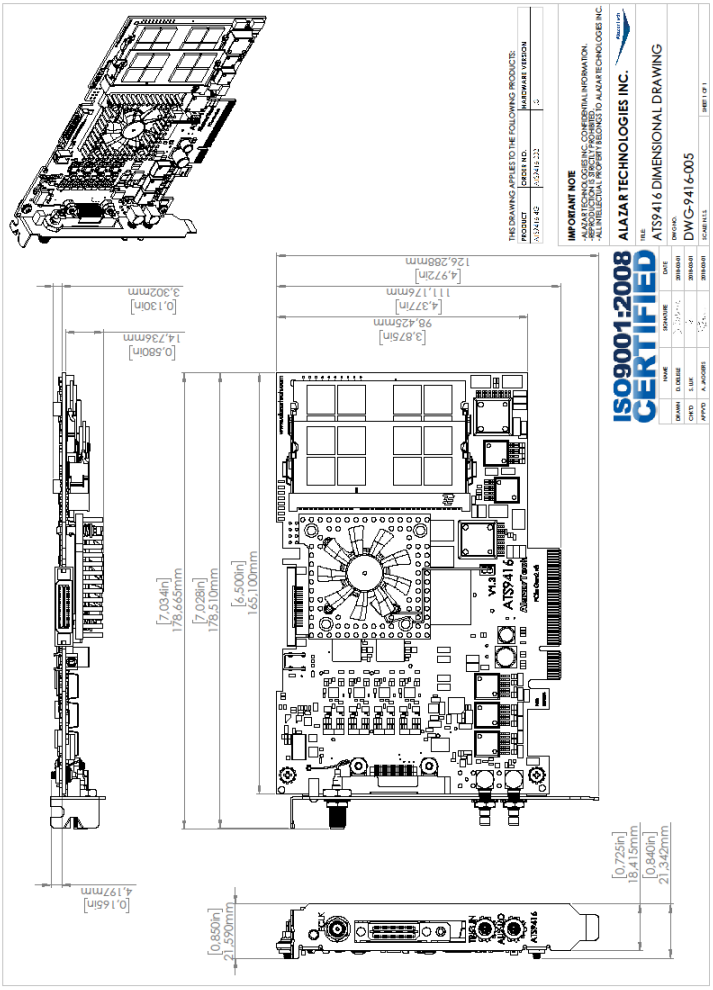


Figure 2 - Mechanical Drawing

Status LEDs

ATS9416 has 9 Status LEDs. Descriptions are provided below in the order in which they appear, from top to bottom, left to right:

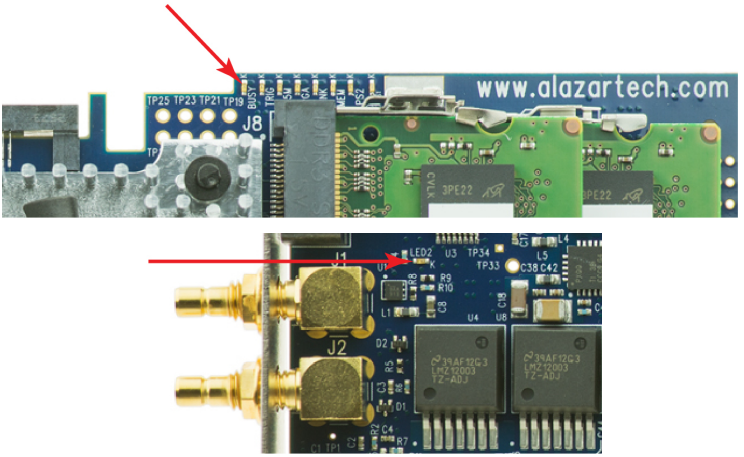


Figure 3 - ATS9416 Status LEDs

- BUSY: This LED being on indicates that the board has been armed for capture. If board is being armed repeatedly, this LED will blink or, if the re-arm rate is very high, may even appear as a dimly lit LED.

- TRIG: This LED being on indicates that the board has received a trigger and is capturing post-trigger data. If board is being triggered repeatedly, this LED will blink or, if the trigger rate is very high, may even appear as a dimly lit LED

- 125M: This LED represents the 125 MHz clock used for the state machine that loads the FPGA. It should always be blinking. This LED being off means that the 125 MHz oscillator is not functioning. This LED being on (solid) indicates one of several possible issues and the customer should Contact Factory.

- FPGA: This LED being on indicates that the FPGA was configured successfully. This LED turn on within 100 milliseconds of the computer power supply becoming stable and should remain on as long as the computer power is on. If this LED is off, it indicates either: a problem in one of the FPGA's power supply circuit; or the on-board flash memory that contains the FPGA configuration data has been corrupted.

- LINK: This LED being ON indicates that a PCIe link has been negotiated between the board and the motherboard. The exact time at which this LED turns on is dependent on the motherboard and its BIOS. Typically, this LED will turn on a few seconds after the FPGA is configured. If the FPGA LED is on but LINK LED does not turn on, it indicates either: the motherboard slot is not enabled by the CPU or the BIOS; or there is a problem in the transceiver power supplies; or one or more of the transceiver coupling capacitors along the gold-fingers on the secondary side have been damaged.

- MEM: This LED indicates that on-board memory is detected by the board. When the software driver is loaded at the start of an application, it forces a full memory test. If the test is completed successfully, this LED is turned on, otherwise it remains off. If this LED is off, remove and reinsert the SO-DIMMs.

- PS2: Power Monitor error output from the board. This LED being red indicates that there is an overheating or power supply issue. Refer to *Figure 4 – Flowchart for Power Monitor Status LEDs* for steps to follow if this LED is red.

- PS1: Power Monitor error output from the board. This LED being red indicates that there is an overheating or power supply issue. Refer to *Figure 4 – Flowchart for Power Monitor Status LEDs* for steps to follow if this LED is red.

- LED3: Power Monitor error output from the board. This LED being red indicates that there is an overheating or power supply issue. *Figure 4 – Flowchart for Power Monitor Status LEDs* for steps to follow if this LED is red.

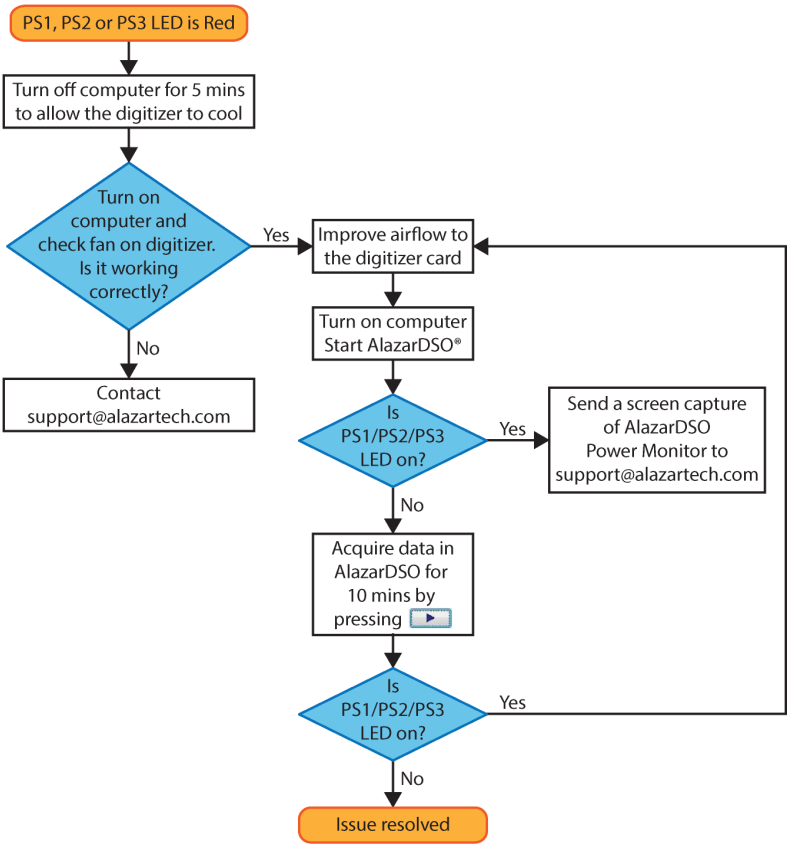


Figure 4 – Flowchart for Power Monitor Status LEDs

Note: for Power Monitor error outputs, the Status LED remains on even after the issue is resolved. To turn off the Status LED, you must press the “Clear Int.” button in the AlazarDSO Power Monitor plug-in or restart the computer.

Signal Connections

ATS9416 uses a high density high bandwidth connector to connect to the outside world. This connector is SAMTEC QSS-025-01-L-D-RA-MTI.

All 16 analog input channels pass through this connector.

External Trigger, AUX I/O and External clock (if External Clock upgrade is installed on your ATS9416) signals use their own coaxial connectors. This was done to minimize crosstalk between these signals and the 16 analog inputs.

ATS9416 CONNECTOR PINOUT			
Pin	**Signal**	**Pin**	**Signal**
1	Not Connected	2	AGND
3	AGND	4	CH P (16)
5	CH M (13)	6	AGND
7	AGND	8	AGND
9	AGND	10	CH N (14)
11	CH O (15)	12	AGND
13	AGND	14	AGND
15	AGND	16	CH L (12)
17	CH I (9)	18	AGND
19	AGND	20	AGND
21	AGND	22	CH J (10)
23	CH K (11)	24	AGND
25	AGND	26	AGND
27	AGND	28	CH H (8)
29	CH E (5)	30	AGND
31	AGND	32	AGND
33	AGND	34	CH F (6)
35	CH G (7)	36	AGND
37	AGND	38	AGND
39	AGND	40	CH D (4)
41	CH A (1)	42	AGND
43	AGND	44	AGND
45	AGND	46	CH B (2)
47	CH C (3)	48	AGND
49	AGND	50	Not Connected
SHIELD		AGND	

You can use CH A (channel 1) to CH P (channel16) to digitize data as well as to trigger an acquisition.

Use the TRIG IN input for an external trigger only; data on the TRIG channel cannot be digitized.

If External Clock Upgrade is installed on your ATS9416, use the ECLK input for clocking the ATS9416 in applications that require an external clock. Consult the chapter Optional External Clock for details on various types of clocking schemes available.

AUX I/O connector can be used as the following I/O's:

Outputs:

- Trigger Output
- Pacer (programmable clock) Output
- Digital Output

Inputs:

- Trigger Enable Input
- Digital Input
- Clock Switchover Control

Analog Input

ATS9416 features 16 analog input channels. Each channel has up to 65 MHz of full power analog input bandwidth. Note that the bandwidth can be increased to 100 MHz by purchasing the Wideband Input Upgrade.

Channels 1 to 8 have a common gain control. Similarly, Channels 9 to 16 have a comon gain control, i.e. if you change the gain of, say, Channel 3, it will change the gain for Channels 1 to 8.

Within the above-mentioned constraint, users can select a full scale input range of ±1 V or ±500 mV. Input impedance of all channels is fixed at 50 Ω. Input coupling of all channels is fixed at DC coupling.

For accurate measurements, make sure the signal being measured is referenced to the same ground as your ATS9416 by attaching the cable's ground shield to the signal ground.

The External Trigger input (labeled TRIG IN) has a digital TTL input with 6.7 kΩ ±10% impedance.

14-bit analog-to-digital converter

ATS9416 uses two state of the art octal (x8) 14-bit ADCs with a maximum conversion rate of 100 MS/s. This means there are a total of 16 individual A/D converters, each running at 100 MS/s.

The 16 channels are guaranteed to be simultaneous, as they use a common clock.

If you use an external clock, you must follow all the timing specifications on the external clock as described in Appendix A, Specifications.

Multiple Record Acquisition

The ATS9416 allows the capture of multiple records into the on-board memory. This allows you to capture rapidly occurring triggers in OCT, ultrasound or spectroscopy applications.

Specifying Record Length

Record Length is specified in number of sample points. It must be a minimum of 256 points and must be a multiple of 128.

Specifying Pretrigger Depth

You can acquire pre-trigger data up to 8176 samples. Minimum value for pre-trigger amount is 0:

From 0 to 8176 for single channel

From 0 to 4088 for dual channel

From 0 to 2044 for quad channel

From 0 to 1022 for 8 channels

From 0 to 511 for 16 channels

Specifying Record Count

User can specify the number of records that must be captured into host PC memory. The minimum value must be 1.

There is no upper limit on how many records you can capture in one acquisition.

Calibration

Calibration is the process of minimizing measurement errors by making small circuit adjustments.

All ATS9416 digitizers come factory calibrated to the levels indicated in Appendix A, Specifications. Note that AlazarTech calibration is fully NIST- or CNRC-traceable.

However, your digitizer needs to be periodically recalibrated in order to maintain its specified accuracy. This calibration due date is listed on the CALIBRATION sticker affixed to your ATS9416 digitizer.

Externally recalibrate the ATS9416 when this calibration interval has expired.

This requires three very simple steps:

1. Verify whether or not ATS9416 is still within its specifications. If it is, then your calibration can be extended by another one-year period
2. If not, perform calibration, i.e. make adjustments to the circuit until it is within specifications again
3. If any adjustments have been made, verify if the ATS9416 is within specifications

Recalibration must be performed at AlazarTech factory.

Optional External Clock

ATS9416 PCI Digitizer optionally allows you to supply the ADC clock. This option is extremely important in many RF applications in which phase measurements must be made between the inputs themselves or between the inputs and an external event.

Another application that requires external clock is Optical Coherence Tomography (OCT) that sometimes requires analog sampling to take place relative to an MZI clock, sometimes also known as k-clock.

Driving high performance ADCs must be done carefully, as any injection of phase jitter through ADC clocks will result in reduction in data conversion quality.

Aside from phase noise, the clock signal for a pipelined ADC must also have a duty cycle close to 50%. This maximizes the dynamic performance of the ADC. See Fast External Clock section below for more details.

External clock input impedance is fixed at 50 Ohms.

External clock input is always AC-coupled.

There are two types of External Clock supported by ATS9416:

- Fast External Clock
- 10 MHz Clock Reference

The following paragraphs describe the two types of External Clock input and outline the restrictions on each of them.

Fast External Clock

This setting must be used when the external clock frequency is in the range of 100 MHz down to Lower Clock Limit of 5 MHz.

It is highly recommended that the Fast External Clock signal have a duty cycle of 50% +/- 5%. However, duty cycle specification can be substantially relaxed at lower frequencies.

If the External Clock supplied is lower than the Lower Clock Limit, measurement quality may be compromised. Measurement errors may include gain errors, signal discontinuities and general signal distortion.

External Clock must be a at least ±200mV sine wave or square wave signal. Maximum amplitude for external clock is ±1V.

The receiver circuit for Fast External Clock is a high speed ECL receiver that translates the input signal into a PECL (Positive ECL) clock signal that features very fast rise times.

Since Fast External Clock is always ac-coupled and selfbiased, there is no need for the user to set the external clock level.

10 MHz Clock Reference

ATS9416 allows the user to synchronize the sampling clock to an external 10 MHz reference signal. This is useful in many RF applications.

Reference clock frequency must be 10 MHz +/- 0.1 MHz. Amplitude can be 200 mV_{P-P} to 1 V_{P-P} sine or square wave.

It should be noted that the 10 MHz reference produces a 100 MHz clock. Users can set lower sampling frequency by specifying a decimation value.

Optional Wideband Input

ATS9416 Wideband Input option provides up to 100 MHz analog input on each of the sixteen channels on the ATS9416. Input impedance of all channels is fixed at 50 Ω.

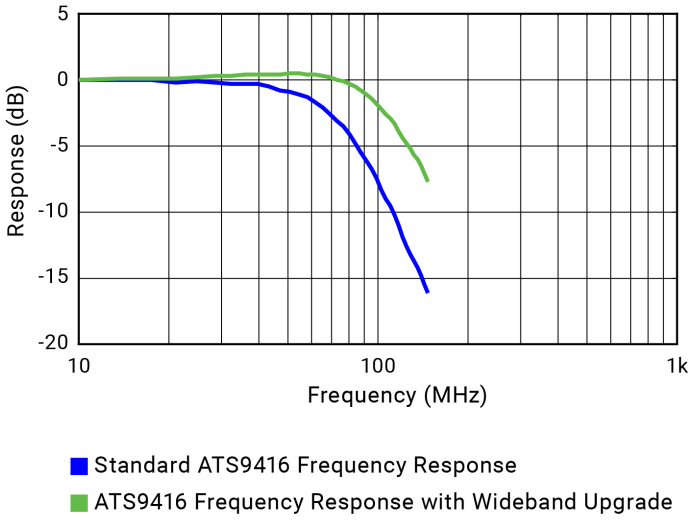


Figure 5 - ATS9416 Frequency Response comparison

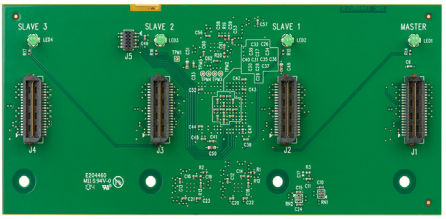
It should be noted that 100 MHz bandwidth can only be achieved with the use the QSS-BNC16 cable and not the breakout board. The maximum bandwidth achievable using the breakout board is 85 MHz.

Optional Accessories

SyncBoard-9416

Users can create a multi-board Master/Slave system by synchronizing up to four ATS9416 boards using an appropriate SyncBoard-9416.

SyncBoard-9416 is a mezzanine board that connects to the Master/Slave connector along the top edge of the ATS9416 and sits parallel to the motherboard.



SyncBoard-9416 is available in different widths: 2x, 4x, 2x-W, 3x-W or 4x-W.

QSS-BNC16 cable

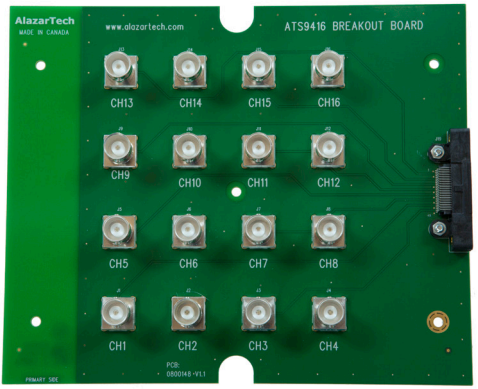
The most popular cable (sold separately) is one that terminates to 16 BNC plugs. This cable is called QSSBNC16 cable.

QSS-QSS cable

For customers who want to design an identical QSS-025-01-L-D-RA-MTI connector on their circuit board, this cable can mate the two QSS connectors.

Breakout Board + QSS-QSS cable

ATS9416 Breakout Board connects to the ATS9416 using a QSS-QSS cable and provides a separate female BNC connector for each analog input. This makes it very easy to connect analog signals to ATS9416 using standard BNC cables.



Chapter 4
Specific Features

This section contains information about features specific to AlazarTech digitizers and ATS9416 in particular.

Streaming Data Across the Bus

One of the most unique features of the ATS9416 is its on-board, dual-port acquisition memory that can act as a very deep Data FIFO and the associated Dual-DMA engine.

This combined by the advanced, fully asynchronous software driver allows data transfer to host PC memory without any appreciable “in-process” software involvement.

These features are particularly useful for applications that require:

a) Continuous, gapless data capture. Also known as “Data Streaming” to PC host memory or hard disk

or

b) Data capture from rapidly occurring triggers, also known as Pulse Repeat Frequency Captures or PRF Captures.

In order to understand these sophisticated features, let us first review some of the issues involved in transferring data under Windows or Linux operating systems.

The Effects of the Operating System

Windows and most Linux distributions are not real-time operating systems, i.e. the operating system cannot guarantee a deterministic response time to an event, such as an interrupt or a software generated event.

This means that if software has to play any appreciable part in data transfer, then the data throughput cannot be guaranteed, as the operating system will have the last say as to when the data collection application will get the CPU cycles to execute the necessary commands.

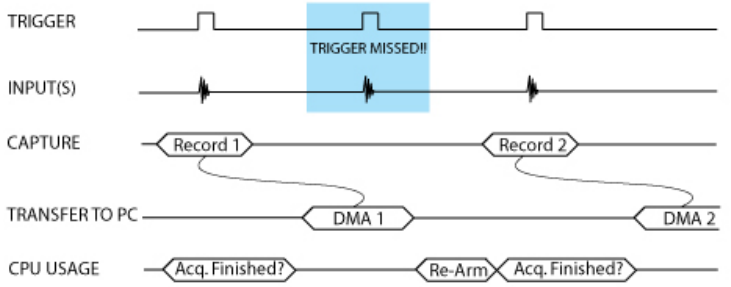
Note that the above is true even if the digitizer claims to use Direct Memory Access (DMA) to do the actual transfer, but uses software commands to re-arm the digitizer. It is the re-arm command that will determine the overall data throughput.

Dual Port Memory

The basic throughput problem faced by digitizers is that almost all of them use single-port memory, i.e. if you are reading data from the acquisition memory, you cannot capture into it and vice-versa.

This requires a software handshake which is heavily dependent on the operating system response time.

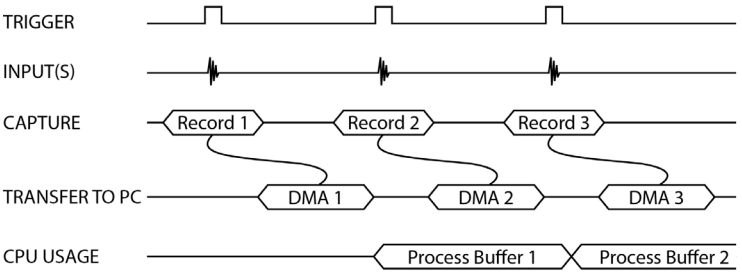
TRIGGERED DATA ACQUISITION USING SINGLE-PORT MEMORY



NOTE 1: Some Trigger events may be missed while data is being off-loaded from on-board memory
NOTE 2: Virtually all CPU cycles are used up in managing data acquisition. Very little left for for data processing

ATS9416 solves this problem by providing a FIFO and an advanced dual-DMA engine that can stream data to PC host memory at up to 3.5 GB/s (exact rate is motherboard dependent).

TRIGGERED DATA ACQUISITION USING DUAL-PORT MEMORY



NOTE 1: No Trigger Events Are Missed - Guaranteed
NOTE 2: Over 95% of CPU cycles are available for data processing

Bottom line is that software does not have to wait until the end of data capture to read the acquired data.

AutoDMA

Just having dual-ported memory or a FIFO, on its own, does not solve the problem of PRF captures or streaming applications. Software still has to get involved in re-arming the hardware after every capture and again for reading the data from on-board acquisition memory.

ATS9416's proprietary AutoDMA circuitry allows the acquisition system to be re-armed by a hardware command and data transfer to be initiated by the hardware itself, thus removing virtually all "in-process" software involvement.

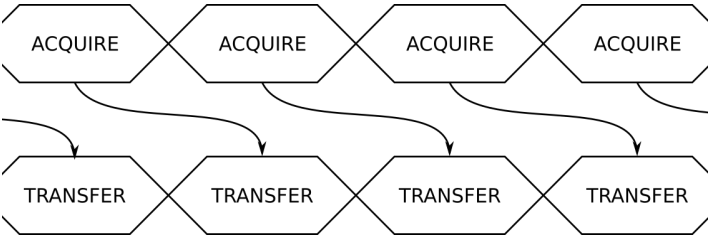


Figure 6 - AutoDMA acquisition and transfer cycle

Of course, software still has to set up the DMA when one of the buffers fills up, but, thanks to the dual-DMA engine and fully asynchronous driver that uses overlapped IO, these tasks can be paralleled.

In other words, when software is re-arming DMA channel 0, DMA channel 1 is already transferring data to host memory.

Note that if data throughput is too high, a DMA_OVERFLOW flag gets set and is available to the programmer.

Consumption of the captured data is, of course, under the control of user-created software, and it is this that will determine the maximum PRF instead of the bus throughput.

The important thing to note is that if asynchronous DMA is used, CPU usage is no more than 5%, even if a 3.5 GB/s DMA is going on.

No Pre-Trigger (NPT) AutoDMA

Many ultrasonic scanning and medical imaging applications do not need any pre-trigger data: only post-trigger data is sufficient.

NPT AutoDMA is designed specifically for these applications. By only storing post-trigger data, the memory bandwidth is optimized and the entire on-board memory acts like a very deep FIFO.

Note that a DMA is not started until RecordsPerBuffer number of records (triggers) have been acquired.

NPT AutoDMA buffers do not include headers. However, users can specify that each record should come with its own footer that contains a 40-bit trigger timestamp. The footer is called NPT Footer.

More importantly, a BUFFER_OVERFLOW flag is asserted only if the entire on-board memory is used up. This provides a very substantial improvement over Traditional AutoDMA.

NPT AutoDMA can easily acquire data to PC host memory at the maximum sustained transfer rate of the motherboard without causing an overflow.

This is the recommended mode of operation for most ultrasonic scanning, OCT and medical imaging applications.

Continuous AutoDMA

Continuous AutoDMA is also known as the data streaming mode.

In this mode, data starts streaming across the PCI bus as soon as the ATS9416 is armed for acquisition. It is important to note that triggering is disabled in this mode.

Continuous AutoDMA buffers do not include headers, so it is not possible to get trigger time-stamps.

A BUFFER_OVERFLOW flag is asserted only if the entire on-board memory is used up.

The amount of data to be captured is controlled by counting the number of buffers acquired. Acquisition is stopped by an AbortCapture command.

Continuous AutoDMA can easily acquire data to PC host memory at the maximum sustained transfer rate of the motherboard without causing an overflow.

This is the recommended mode for very long signal recording.

Triggered Streaming AutoDMA

Triggered Streaming AutoDMA is virtually the same as Continuous mode, except the data transfer across the bus is held off until a trigger event has been detected.

Triggered Streaming AutoDMA buffers do not include headers, so it is not possible to get trigger time-stamps.

A BUFFER_OVERFLOW flag is asserted only if the entire on-board memory is used up.

As in Continuous mode, the amount of data to be captured is controlled by counting the number of buffers acquired.

Acquisition is stopped by an AbortCapture command.

Triggered Streaming AutoDMA can easily acquire data to PC host memory at the maximum sustained transfer rate of the motherboard without causing an overflow.

This is the recommended mode for RF signal recording that has to be started at a specific time, e.g. based on a GPS pulse.

Stream To Memory

AlazarDSO features a free ‘Stream To Memory’ module which allows it’s users to acquire data to computer RAM and to analyse it or save it to disk later. This is very useful in cases where the acquisition data rate is higher than the disk writing speed, but the total acquisition size is less than the free RAM of the computer.

This module is accessed by clicking on Tools >> Stream To Memory…

Appendix A - Specifications

This appendix lists the specifications of the ATS9416. These specifications are typical at 25 °C unless otherwise stated. The operating temperature range is 0 to 55 °C.

Minimum Requirements

OS	Windows 10, Windows 8.x, Windows 7, Windows Server 2013, Windows Server 2010 or Windows Server 2008 R2 (both 32 and 64 bit), or one of the *Supported Linux Distributions*
RAM	16 GB
HDD	100 MB of free hard disk space
PCI Slot	One free PCIe slot that is mechanically x8 or x16.

Recommended Motherboard Specifications

PCI Express revision	2.0a or higher
PCI Express Transceiver speed	5 Gbps
PCI Express Port lanes	8
Compatibility - mechanical	x8 and x16 slots
Compatibility - electrical	x1, x4, x8 and x16 slots

Power Requirements

+12 V	1.8 A, typical
+3.3 V	2.0 A, typical

Physical

Size	Single slot, half-length PCIe card (4.377 inches x 6.5 inches excluding the connectors protruding from the front panel)
Weight	250 g

I/O Connectors

Analog connector	SAMTEC QSS-025-01-L-D-RA-MTI
External Trigger	SMB female
Auxiliary IO	SMB female
External Clock	SMA female

Environmental

Operating temperature	0 to 55 °C
Storage temperature	-20 to 70 °C
Relative humidity	5 to 95%, non-condensing

Acquisition System

Resolution	14 bits
Bandwidth (-3 dB)	
DC-coupled, 50 Ω	DC - 65 MHz, typical for all input ranges With wideband input option, the bandwidth increases to DC - 100 MHz
Number of channels	16, simultaneously sampled
Max. Sample Rate	100 MS/s single shot
Min. Sample Rate	100 KS/s single shot for internal clocking
Full Scale Input range	
50 Ω input impedance	±1 V, fixed
DC accuracy	±2% of full scale in all input ranges
Input coupling	DC coupling only
Input impedance	50 Ω ± 5%
Input protection	±4 V (DC + peak AC)

Acquisition Memory System

Memory Size	Single Channel: 4G samples per channel Dual Channel: 2G samples per channel Quad Channel: 1G samples per channel Octo Channel: 512M samples per channel 16 Channel: 256M samples per channel
Record Length	Software selectable with 128-point resolution. Record length must be a minimum of 256 points. There is no upper limit on the maximum record length.
Number of Records	Software selectable from a minimum of 1 to a maximum of infinite number of records
Pre-trigger depth	From 0 to 8176 for single channel From 0 to 4088 for dual channel From 0 to 2044 for quad channel From 0 to 1022 for 8 channels From 0 to 511 for 16 channels

Post-trigger depth	Record Length – Pre-Trigger Depth

Timebase System

Timebase options	Internal Clock or External Clock (Optional)
Internal Sample Rates	100 MS/s, 50 MS/s, 20 MS/s, 10 MS/s, 5 MS/s, 2 MS/s, 1 MS/s, 500 KS/s, 200 KS/s, 100 KS/s
Internal Clock accuracy	±2 ppm

Dynamic Parameters

Typical values measured on CH 1 of a randomly selected ATS9416. Input signal was provided by an SRS SG384 signal generator, followed by a 9-pole, 10 MHz band-pass filter (TTE Q36T-10M-1M-50-720BMF). Input frequency was set at 10 MHz and output amplitude was 0.670 Vrms, which is approximately 95% of the full scale input. FFT was averaged.

SNR	66.8 dB
SINAD	65.6 dB
THD	-72.1 dB
SFDR	-73.5 dB

Note that these dynamic parameters may vary from one unit to another, with input frequency and with the full scale input range selected.

Optional ECLK (External Clock) Input

Signal Level	200 mV_{P-P} to 1 V_{P-P}
Input impedance	50 Ω
Input Coupling	AC
Maximum frequency	100 MHz for Fast External Clock
Minimum frequency	5 MHz for Fast External Clock
Sampling Edge	Rising
Maximum Amplitude	2 V_{P-P}

Optional 10 MHz Reference Input

Signal Level	200 mV_{P-P} to 1 V_{P-P}
Input impedance	50 Ω
Input Coupling	AC coupled
Input Frequency Maximum frequency Minimum frequency	10 MHz ± 0.1 MHz 10.1 MHz 9.9 MHz
Sampling Clock Freq.	100 MHz

Triggering System

Mode	Edge triggering with hysteresis
Comparator Type	Digital comparators for internal (CH A ~ CH P) triggering and TTL receiver for TRIG IN (External) triggering
Trigger Engines	2
Trigger Engine Combination	Engine J, engine K, J OR K, software selectable
Trigger Engine Source	Any one of CH A ~ CH P, TRIG IN, Software or None, independently software selectable for each of the two Trigger Engines
Hysteresis	±5% of full-scale input, typical
Trigger sensitivity	±10% of full scale input range. This implies that the trigger system may not trigger reliably if the input has an amplitude less than ±10% of full-scale input range selected
Trigger level accuracy	±5%, typical, of full-scale input range of the selected trigger source
Bandwidth	65 MHz
Trigger Delay	Software selectable from 0 to 9,999,999 sampling clock cycles. Has to meet alignment requirements (see ATS-SDK Guide for more information)
Trigger Timeout	Software selectable with a 10 µs resolution. Maximum settable value is 3,600 seconds. Can also be disabled to wait indefinitely for a trigger event

TRIG IN (External Trigger) Input

Input range	3.3V TTL Input (5 V compliant)
Input impedance	6.7 kΩ ±10% for TTL input
Input coupling	DC only
Bandwidth (-3 dB)	DC - 65 MHz
Min. pulse width	32 ADC sampling clocks
Min. pulse amplitude	2 Volts
Input protection	±5 V (DC + peak AC without external attenuation)

Auxiliary I/O (AUX I/O)

Signal direction	Input or Output, software selectable. Trigger Output by default
Output types:	Trigger Output, Busy Output, Software controlled Digital Output
Input types:	Trigger Enable Software readable Digital Input
Output	
Amplitude:	5 Volt TTL
Synchronization:	Synchronized to a clock derived from the ADC sampling clock. Divide-by-8 clock (dual channel mode) or divide-by-16 clock (single channel mode)
Input	
Amplitude:	3.3 Volt TTL (5 Volt compliant)

Certification and Compliances

RoHS 3 (Directive 2015/863/EU) Compliance

CE Mark Compliance

FCC Part 15 Class A / ICES-003 Class A Compliance

Materials Supplied

One ATS9416 PCI Express Card

One ATS9416 Install Disk on USB flash drive

Supported Linux Distributions

AlazarTech offers ATS9416 binary drivers for most of the popular linux distributions, such as CentOS, Ubuntu,...

Users can download the binary driver for their specific distribution by choosing from the available drivers here:

ftp://release@ftp.alazartech.com/outgoing/linux

All specifications are subject to change without notice

Appendix B - Benchmarks

This appendix lists the data throughput measured by our technicians on various computers and motherboards under different operating systems.

Given the constantly changing nature of computers, these benchmarks are provided as a reference only and AlazarTech assumes no liability in case the computer you purchase behaves differently than what was observed in AlazarTech's laboratory.

The following motherboards and computers showed comparable results under Windows 10 and Linux REHL 7:

Model	Throughput
ASUS Maximus VIII Impact	3.5 to 3.6 GB/s
Asrock X79 Extreme11	
HP Z440 Workstation	
HP Z840 Workstation	

Note: To ensure optimum performance, you should always make sure to use the latest BIOS. Most motherboard-related issues we see are fixed with a BIOS update.

List of AlazarTech Recommended Motherboards & PCs

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