



AlazarTech

ATS9351 User Manual

**12 Bit, 500 MS/s
Waveform Digitizer for PCI Express Bus**



Written for Hardware Version 1.8
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Part Number: 9351-USR-8

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Serial Number: _____

Purchase Date: _____

Purchased From: _____

Software Driver Version: _____

SDK Version: _____

AlazarDSO Version: _____

Operating System: _____

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FCC/Canada Radio Frequency Interference Compliance*

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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 communications (DOC), of Industry Canada, 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/DOC 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 web site <http://www.fcc.gov> for more information.

FCC/DOC 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 the Canadian Department of Communications (DOC).

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

Canadian Department of Communications

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations. *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 <http://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 2002/95/EC of the European Parliament and of the Council of 27 January 2003 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.

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Chapter 1 - Introduction

This chapter describes the ATS9351 and lists additional equipment.



About Your ATS9351

Thank you for your purchase of an ATS9351. This PCI Express (PCIe x8) based waveform digitizer has the following features:

- Two 12-bit resolution analog input channels
- Real-time sampling rate of 500 MS/s to 1 KS/s with internal clock and 500 MS/s to 1 MS/s with external clock
- On-board acquisition memory buffer of up to 2 Gigasamples (4 Gigabytes)
- Streaming of acquired data to PC host memory at 1.6 GB/s (exact rate is motherboard dependent)
- 250 MHz analog input bandwidth
- Half length PCI Express (8 lane) card
- Analog trigger channel with software-selectable level and slope
- Fixed DC coupling, fixed 50 Ω input impedance and fixed +/- 400mV full scale input range
- Pre-trigger and Post-Trigger Capture with Multiple Record capability
- Multi-board Master/Slave systems for up to 8 simultaneous input channels
- NIST 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 ATS9351 digitizers follow industry-standard Plug and Play specifications on all platforms and offer seamless integration with compliant systems.

If your application requires more than two channels for data acquisition, you can synchronize multiple digitizers on all platforms using a Master/Slave SyncBoard 9351.

Detailed specifications of the ATS9351 digitizers are listed in Appendix A, Specifications.

Acquiring Data with Your ATS9351

You can acquire data either programmatically by writing an application for your ATS9351 or interactively with the AlazarDSO software.

If you want to integrate the ATS9351 in your test and measurement or embedded OEM application, you can program the digitizer using C/C++, Visual BASIC or LabVIEW for Windows or C for Linux operating systems.

- Windows operating systems supported are Windows 7 32bit, Windows 7 64 bit, Windows Vista 32 bit, Windows Vista 64 bit, Windows XP 32 bit and Windows XP 64 bit.
- Note that Windows 98SE and Windows 2000 are not supported.

For programming in C/C++ or Visual BASIC, you must purchase the ATS-SDK software development kit that comes with sample programs and a reference manual describing the API.

For programming in LabVIEW, you must purchase the ATS-VI virtual instrument library that comes with a high-level, easy-to-use VI that makes integrating the ATS9351 into your own system very simple.

It is also possible to program your ATS9351 under Linux operating system. CentOS 6.3 (compatible with RHEL 6.3) binary drivers for ATS9351 are included with ATS-SDK.

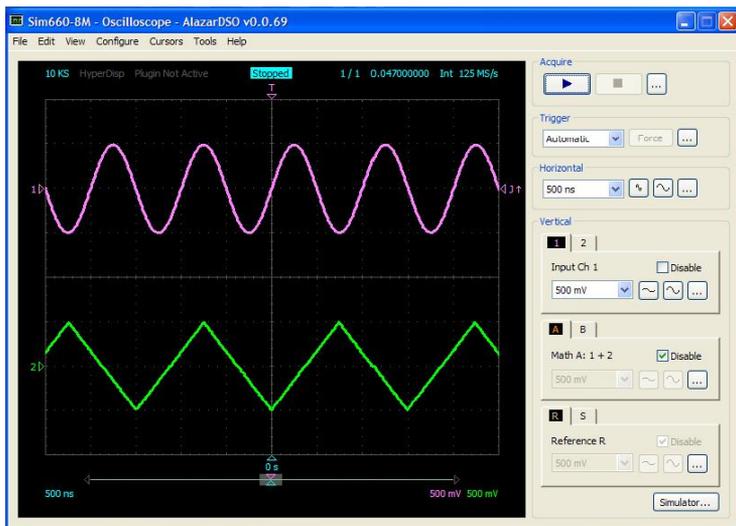
For Linux distributions other than CentOS 6.3, it is the user's responsibility to compile the appropriate drivers. Users will need to sign a Non-Disclosure Agreement with AlazarTech and purchase the ATS-Linux software development kit that comes with source files for the driver and C source code for a sample program. Also supplied is the AlazarFrontPanel graphical user interface for the ATS9351.

Interactively Controlling your ATS9351 with AlazarDSO

The AlazarDSO Soft Front Panel allows you to interactively control your ATS9351 as you would a desktop oscilloscope. To launch the Scope Soft Front Panel, select

Start » Programs » AlazarTech » AlazarDSO

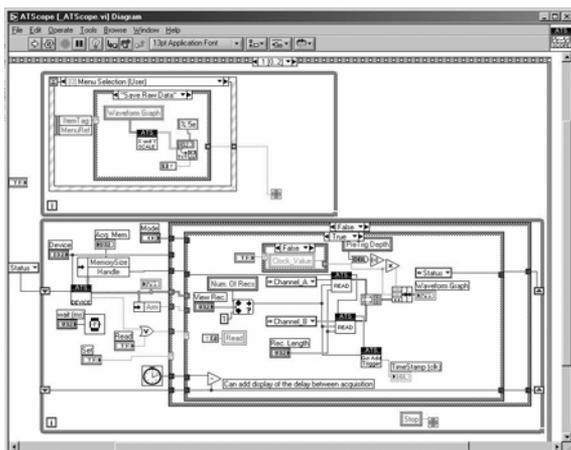
The following screen will be displayed. If you connect the input to a signal generator and click on **Start** button, you should see the signal on the screen.



AlazarDSO has been designed to be very intuitive and uses a user interface similar to most of today's digital oscilloscopes.

ATS-VI LabVIEW VI

ATS-VI allows you to integrate the ATS9351 into your own LabVIEW program. A high level VI is supplied that requires very few controls to get started.



ATS-Linux for ATS9351

The ATS-Linux for ATS9351 can be used for programming the ATS9351 under Linux operating system. A source code driver is supplied that has been compiled for CentOS 6.3 (Kernel 2.6) running on an i386 platform. Sample program is supplied in C. The API is identical to the Windows API.

Note that you will need to sign a Non-Disclosure Agreement with AlazarTech in order for the source code of the drivers to be shared with you.

Optional Upgrades

AlazarTech offers the following upgrades and accessories for use with your ATS9351 digitizer:

- ATS9351: External Clock Upgrade
- ATS9351: Master/Slave SyncBoard 2 position
- ATS9351: Master/Slave SyncBoard 4 position
- AlazarDSO – Stream To Disk Module
- AlazarDSO – Plug-In Development Kit
- ATS-GPU – Software framework for GPU interface

Chapter 2 - Installation and Configuration

This chapter describes how to unpack, install, and configure your ATS9351.

What You Need to Get Started

To set up and use your ATS9351, you will need the following:

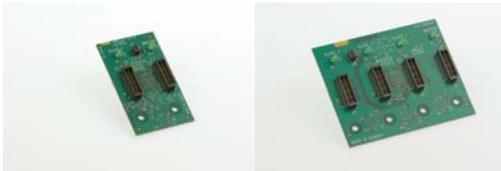
- One or more ATS9351 digitizers



- ATS9351 Installation Software on USB Disk



- For Master/Slave operation only:
SyncBoard of appropriate width



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 ATS9351

There are four main steps involved in installation:

1. Physically install the digitizer(s) and SyncBoard, if any, in your computer.
2. Install ATS9351 software driver
3. Install AlazarDSO software that allows you to setup the hardware, acquire signals and view and archive them
4. Optionally, install the ATS-SDK software development kit or ATS-VI LabVIEW VI, which enables you to programmatically control the ATS9351

Thanks to the flexible nature of AlazarTech's driver installation software, you can either install the hardware first or install the software driver first.

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 ATS9351 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 ATS9351 digitizer in one of the free PCI Express slots.

For best noise performance, leave as much room as possible between your ATS9351 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, ATS9351 is not guaranteed to operate within the specifications listed elsewhere in this manual.

Some motherboards may have a 16-lane connector, but only one of the lanes is connected to the motherboard chipset. Motherboard manufacturers refer to this as “Mechanically 16-lane, electrically 1 lane”. ATS9351 is fully compatible with such motherboards, but the data throughput across PCI Express bus will be limited by the number of lanes.

2. **For Master/Slave Installation**

If you are installing multiple ATS9351 digitizers that will be configured as a Master/Slave system, make sure that you insert all cards in adjacent slots.

The connector on the SyncBoard that is labeled as "M" (Master), must be inserted into the Master/Slave connector of the left-most digitizer, if you are facing the BNC connectors of the ATS9351 digitizers.

Make sure you screw in the SyncBoard to the screw bracket on the ATS9351 printed circuit board.

If you are installing fewer than the maximum number of digitizers supported by your SyncBoard, the unused SyncBoard connectors must be on the right-hand side of the digitizers, if you are facing the BNC connectors of the ATS9351 digitizers.

Once you have completed this step, you should power the computer on.

3. **Install ATS9351 software driver**

The following instructions guide you through the process of installing the ATS9351 in a computer running Windows 7, Windows Vista or Windows XP operating systems.

Other operating systems, such as Windows NT, Windows 2000, Windows 95 and Windows 98SE are not covered here.

Note that the images of the dialog boxes shown below were taken from a Windows XP computer. Computers running Windows 7 or Vista may have slightly different dialog boxes.

Installation of Multiple ATS9351 Digitizers

If you are installing multiple ATS9351 digitizers, the operating system will detect one card at a time and you will have to go through the driver installation setup as many times as you have cards.

Installing ATS9351 Hardware First

If you decided to install the ATS9351 hardware before installing the ATS9351 software driver, then when you first boot up the computer, the plug-n-play Windows operating system will detect the presence of a new PCI card and ask you to provide the device driver.

- a) When you power on for the first time, Windows will display the **Welcome to the Found New Hardware Wizard**



Click **Cancel**.

- b) Insert the installation disk. If it does not auto-run, manually run the Setup.exe program on the ATS9351 Driver Disk. The following splash screen will be displayed:

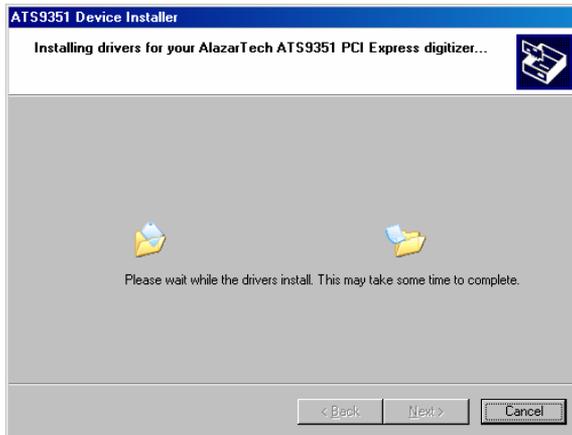


- c) Click on **Install ATS9351 Driver**

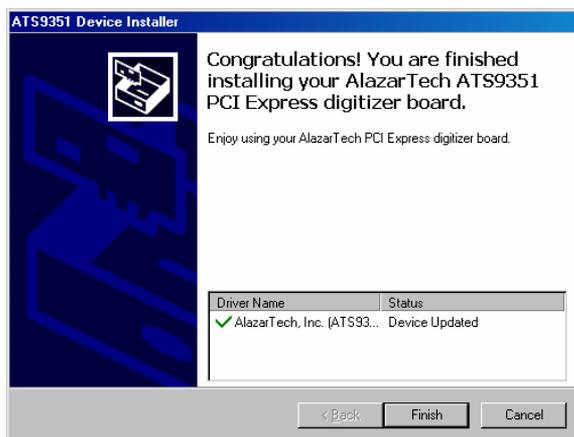


Click **Next**.

- d) The following dialog box will be displayed showing the progress of installation of ATS9351 driver files in the operating system driver store.



- e) The following final screen will confirm that the driver has been installed.



Now your ATS9351 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 drive shipped with the ATS9351 digitizer:

- Insert the ATS9351 Install disk and run Autorun



- 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. **DO NOT RUN SETUP.EXE FROM WITHIN THE ZIP FILE**
- Browse to the folder that contains the unzipped file, Setup.exe
- Run this executable file and follow the instructions on the screen.

4. **Optionally, install the ATS-SDK software development kit or ATS-VI LabVIEW VI, which enables you to programmatically control the ATS9351**

Insert the ATS-SDK or ATS-VI CD. Software installation will start automatically.

If, for any reason, installation does not start automatically, run the SETUP.EXE program.

Follow the instructions on the screen.

Note that you must have already installed the ATS9351 drivers for any of the sample programs included with the ATS-SDK or ATS-VI to work properly.

Installing the ATS9351 in a Linux System

ATS9351 is fully compatible with the popular Linux operating system.

Binary drivers for 64-bit CentOS 6.3 (kernel 2.6.32-279.5.2.el6.x86_64) are included with ATS-SDK.

If you need to operate in a different Linux distribution, you must compile the drivers for that distribution. AlazarTech supplies source code Linux drivers that have been tested under CentOS 6.3.

- Note that a Non-Disclosure Agreement must be signed between AlazarTech and your company or university before any source code can be released to you.

AlazarTech does not provide software support for compiling drivers for other versions of Linux, i.e. customers will be fully responsible for compiling drivers for their own Linux operating system.

To install Linux drivers in a CentOS 6.3 system, follow the instructions listed below:

1. Copy the supplied RPM file to the target machine
2. Double-click on the RPM icon. This will install the driver as well as associated applications.

The RPM file will also install an application called AlazarFrontPanel. This is a Graphical User Interface (GUI) using which you can setup and acquire data from the ATS9351 **using single port memory only**.

Note that AlazarFrontPanel has been compiled using GTK 2.4 libraries. Make sure that the GTK 2.4 libraries have been installed on your machine.

Compiling the ATS9351 Linux Driver

If you need to compile the ATS9351 driver for a version of Linux other than CentOS 6.3, follow these steps:

1. Install the Linux kernel header files.
2. Extract the driver sources from "PlxLinux_ATS9351_*.tgz ". This will create a folder names "PlxLinux" with the driver files inside.
3. Set the shell environment variable PLX_SDK_DIR to the root location where the "PlxLinux" directory was created. For example, if using bash and the PlxLinux directory is in your home directory, then add the following line to the ~/.bashrc :

```
declare -x PLX_SDK_DIR=$HOME/PlxLinux
```

4. To build the ATS9351 driver, type

```
cd PlxLinux/linux/driver
./make
```

This will create the file ATS9351.ko, the loadable driver file. You can change build defines in PlxLinux/linux/makefiles/Gcc.def. Copy the driver to /usr/local/AlazarTech/bin.

5. Load the driver by rebooting the computer or typing:

```
cd /usr/local/AlazarTech/bin
ATS9351.rc start
```

You should be able to run the AlazarFrontPanel application or ATS-SDK example programs in /usr/local/AlazarTech/samples.

6. If it is necessary to rebuild the library, type

```
cd PlxLinux/linux/api
make
```

This will create SharedLibrary/libPlxApi.so.0.0. Copy the file to /usr/local/AlazarTech/lib and then run ldconf

Updating ATS9351 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 ATS9351 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.

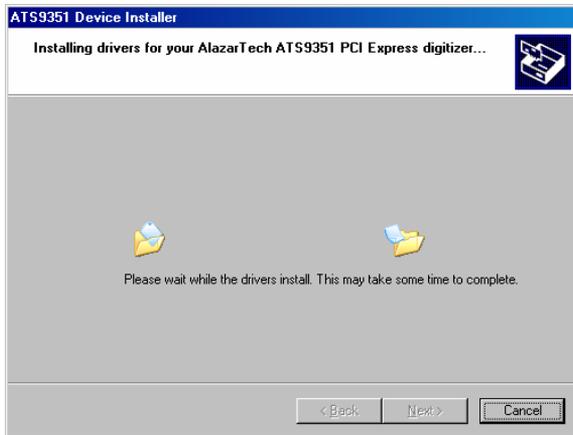
1. Download the latest driver from AlazarTech's web site:
www.alazartech.com/support/downloads.htm
2. Unzip the downloaded file to a local folder.
DO NOT TRY TO RUN INSTALLATION PROGRAM FROM WITHIN THE ZIP FILE
3. Run the resulting installation file (*.exe extension).
For example, the installation file for driver version 5.8.0 is called **ATS9351_Driver_V5.8.0.exe**.

The following welcome screen will be displayed:



Click **Next**.

- The following dialog box will be displayed showing the progress of installation of ATS9351 driver files.



- The following final screen will confirm that the driver has been installed.



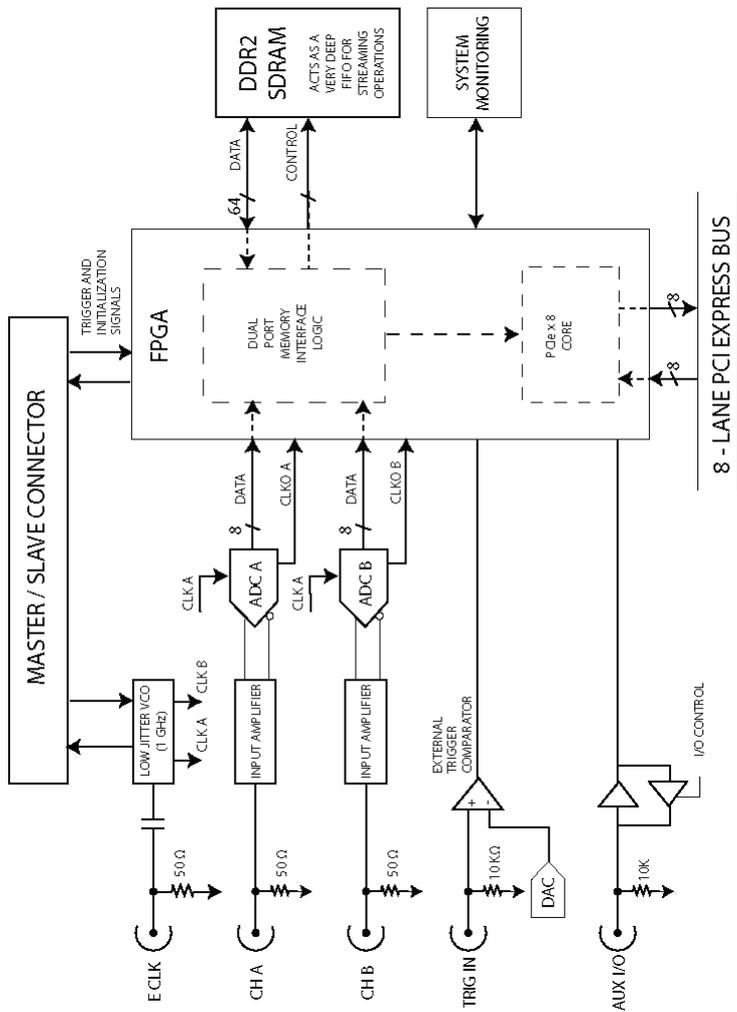
Click **Finish**.

ATS9351 driver has now been updated

Chapter 3 - Hardware Overview

This chapter includes an overview of the ATS9351, explains the operation of each functional unit making up your ATS9351, and describes the signal connections.

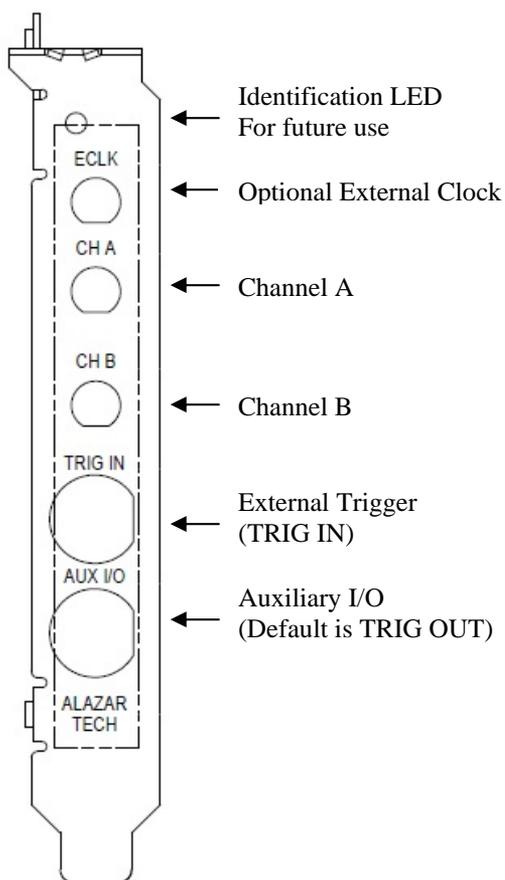
Following is a high-level block diagram of ATS9351.



Input Connectors

ATS9351 digitizers have one SMA connector for ECLK (External Clock) Input, two SMA connectors for CH A and CH B analog input connections, one BNC female connector for the TRIG IN (External Trigger) input and one BNC female connector for AUX I/O (Auxiliary Input or Output).

The following pictorial shows the various connectors available on the digitizer bracket.



Signal Connections

You can use CH A and CH B to digitize data as well as to trigger an acquisition.

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

If External Clock Upgrade is installed on your ATS9351, use the ECLK input for clocking the ATS9351 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 for outputting TRIG OUT signal, a 5 V TTL signal synchronous with the on-board trigger signal and the sampling clock.

- Note that the AUX I/O connector can also be configured as a Trigger Enable Input through a software command.

Analog Input

The two analog input channels are referenced to common ground in bipolar mode. These settings are fixed; therefore, neither the reference nor the polarity of input channels can be changed. You cannot use CH A or CH B to make differential measurements or measure floating signals unless you subtract the digital waveforms in software.

For accurate measurements, make sure the signal being measured is referenced to the same ground as your ATS9351 by attaching the probe's ground clip to the signal ground.

The External Trigger input (labeled TRIG IN) either has a fixed input range of ± 3.3 V with 50Ω input impedance, or can be configured as a TTL input with $3\text{ K}\Omega$ input impedance. The latter is very useful for applications in which the circuit generating the External Trigger signal cannot drive a 50Ω load.

The CH A and CH B inputs have a fixed DC coupling, a fixed 50Ω input impedance and a fixed ± 400 mV full scale input range.

The fixed input range is one of the main differentiators between ATS9351 and ATS9350, AlazarTech's other 500 MS/s 12 bit waveform digitizer. Due to this fixed input range, ATS9351 provides a > 5 dB improvement in SNR (signal-to-noise-ratio).

Monolithic 12-bit ADC

ATS9351 uses two monolithic analog-to-digital converters with a maximum conversion rate of 500 MS/s.

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 ATS9351 allows the capture of multiple records into the on-board memory. This allows you to capture rapidly occurring triggers in OCT, ultrasound or radar applications.

Note that ATS9351 allows you to acquire pre-trigger data.

Specifying Record Length

Record Length is specified in number of sample points. It must be a minimum of 256 points and can be specified with a 64-sample resolution.

Specifying Pretrigger Depth

You can acquire pre-trigger data up to the limit of (Record length – 256). Minimum value for pre-trigger amount is 0.

Specifying Record Count

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

The maximum Record Count value in single-port mode is 1000.

In dual-port memory mode, 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 ATS9351 digitizers come factory calibrated to the levels indicated in Appendix A, Specifications. Note that AlazarTech calibration is fully NIST 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 ATS9351 digitizer.

Externally recalibrate the ATS9351 when this calibration interval has expired.

This requires three very simple steps:

1. Verify whether or not ATS9351 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 ATS9351 is within specifications

Calibration Verification procedures are available to all registered users of ATS9351 as part of AlazarDSO software.

Calibration software can be purchased by qualified customers and metrology laboratories.

Optional External Clock

ATS9351 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 three types of External Clock supported by ATS9351:

- Fast External Clock
- Slow External Clock
- 10 MHz Clock Reference

The following paragraphs describe the three 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 2 MHz to 500 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 2 MHz, measurement quality may be compromised. Measurement errors may include gain errors, signal discontinuities and general signal distortion.

If you want to clock slower than the lower limit of Fast External Clock, you must use the Slow External Clock range.

External Clock must be a sine wave or square wave signal with amplitude in the range of $100 \text{ mV}_{\text{p-p}}$ to $1 \text{ V}_{\text{p-p}}$.

The receiver circuit for Fast External Clock is a high speed analog comparator 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 self-biased, there is no real need for the user to set the external clock level. However, in some cases of burst mode clocking, the user may have to adjust this level for optimal operation.

Dummy Clock Switchover is another useful feature for OCT applications that use Fast External Clock. In these applications, the user-supplied clock is not of constant frequency and may even be out of specification at certain times.

The unique Dummy Clock Switchover capability of ATS9351 allows the sampling clock to be switched to a nominal 100 MHz clock while the user-supplied clock is out of specification. The amount of time for which the Dummy Clock remains in operation can be set programmatically by the user.

Slow External Clock

This setting must be used when the external clock frequency is slower than the lower limit of Fast External Clock.

In this range, the input clock is tracked by the 125 MHz internal clock and a sample is taken on every rising or falling clock edge. As such, there will be a timing error of 0 to 8 nanoseconds. For low bandwidth signals, this error can be considered to be negligible.

Slow External Clock signal must be a 3.3 Volt TTL signal.

10 MHz Clock Reference

ATS9351 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 +/- 0.5 MHz. Amplitude can be a sine or square wave from $100 \text{ mV}_{\text{p-p}}$ to $1 \text{ V}_{\text{p-p}}$.

It should be noted that the 10 MHz reference produces a 500 MHz clock. Users can set lower sampling frequency by specifying a decimation value.

Streaming Data Across the Bus

One of the most unique features of the ATS9351 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 Linux 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.

For example, it is very common for PCI digitizers that boast very fast throughput to slow down considerably when capturing pulsed radar or ultrasonic signals at Pulse Repeat Frequency (PRF) of 1 KHz or so, even though each capture is only 2048 bytes (a paltry 2 MB/s throughput).

In other words, digitizers that specify raw data throughput of 100 MB/s can hardly handle 2MB/s effective throughput due to operating system related delays in issuing re-arm commands.

Real-Time Operating Systems

Some vendors claim that switching to a real-time operating system (RTOS) can solve the problems involved in PRF data capture.

Before switching to an expensive RTOS (such as VxWorks, QNX or PharLap ETS), ask the vendor of the operating system, the supplier of your PC system and manufacturer of the digitizer board if they are all guaranteed to be 100% compatible and interoperable with each other with deterministic interrupt latencies and if you will get your money back if the system does not work at your PRF rates with your software.

Here is an excerpt from a FAQ section of one such supplier of RTOS:

Question: How do system configuration and CPU selection impact the interrupt latency?

Answer: Hardware platforms and the configuration of the associated drivers that use the hardware do impact response times. Some of the common issues include:

Video cards - some of the higher-end cards lock-out (or busy-wait) the bus for extended periods of time to improve their performance.

DMA devices - devices which burst DMA for lengthy period.

Power management which cycles off the CPU during IDLE CPU periods.

Memory speeds, processor speeds, etc.

A PCI or PCI Express digitizer being used in a PRF or streaming application is, by definition, doing "burst DMA for lengthy period", and is a type of product that can negatively impact response times of the RTOS.

As such, the claim that an RTOS can remove all timing uncertainties in PRF application is suspect, to say the least.

Furthermore, you may not be able to get software drivers for the selected RTOS for all the hardware components you need for your system.

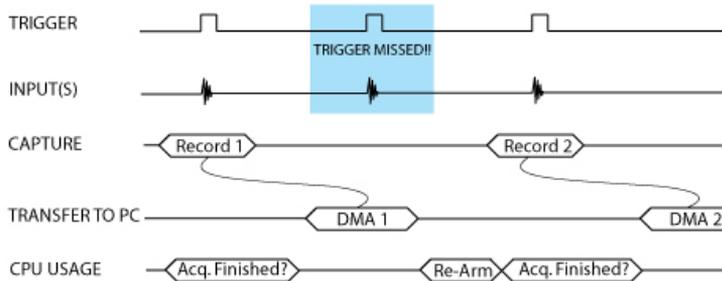
In summary, moving to a real-time operating system will not guarantee data throughput, but will surely increase the overall system cost, increase the cost of software development and maintenance and limit the number of suppliers for other hardware components.

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

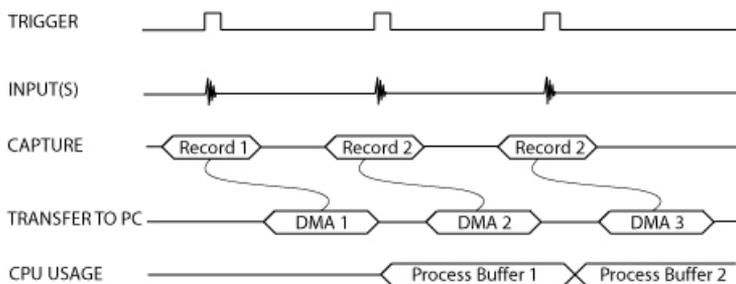


NOTE 1: Some Trigger events may be missed while data is being off-loaded from on-board memory

NOTE 2: Virtually all CPU cycles are used up in managing data acquisition. Very little left for for data processing

ATS9351 solves this problem by providing dual-port memory that can act as a very deep FIFO and an advanced dual-DMA engine that can stream data to PC host memory at up to 1.4 GB/s (exact rate is motherboard dependent).

TRIGGERED DATA ACQUISITION USING DUAL-PORT MEMORY



NOTE 1: No Trigger Events Are Missed - Guaranteed

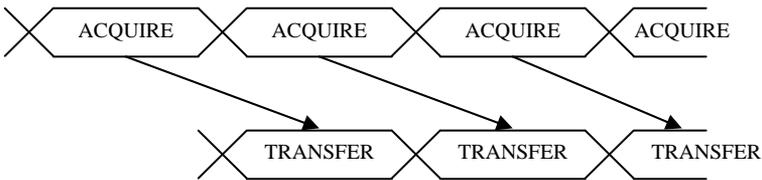
NOTE 2: Over 95% of CPU cycles are available for data processing

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.

ATS9351'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.



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 1.4 GB/s DMA is going on.

Traditional AutoDMA

In order to acquire both pre-trigger and post-trigger data in a dual-ported memory environment, users can use Traditional AutoDMA.

Data is returned to the user in buffers, where each buffer can contain from 1 to 8192 records (triggers). This number is called RecordsPerBuffer.

Users can also specify that each record should come with its own header that contains a 40-bit trigger timestamp.

A BUFFER_OVERFLOW flag is asserted if more than 512 buffers have been acquired by the acquisition system, but not transferred to host PC memory by the AutoDMA engine.

While Traditional AutoDMA can acquire data to PC host memory at the maximum sustained transfer rate of the motherboard, a BUFFER_OVERFLOW can occur if more than 512 triggers occur in very rapid succession, even if all the on-board memory has not been used up.

No Pre-Trigger (NPT) AsyncDMA

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, so it is not possible to get trigger time-stamps.

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 AsyncDMA

Continuous AutoDMA is also known as the data streaming mode.

In this mode, data starts streaming across the PCI bus as soon as the ATS9351 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 AsyncDMA

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 Disk

Any one of the AutoDMA modes can be combined with a fast disk drive to create a very efficient and low cost data streaming system.

AlazarDSO Stream To Disk module (sold separately) allows out-of-the-box disk streaming. No programming is required. Note, however, that the speed with which data can be stored to memory will be limited by the lower of:

1. ATS9351 Bus Throughput (1.6 GB/s)
2. PCI Express throughput supported by the motherboard
3. Sustained Throughput of the disk drive system

AlazarDSO includes a Disk Throughput Benchmarking tool, using which you can quickly and easily see how fast your disk drives are.

Files are saved as ATB format binary files, and can automatically be converted to text files or MATLAB compatible files.

For more information on complete disk streaming systems, please contact the factory or your local distributor.

Appendix A - Specifications

This appendix lists the specifications of the ATS9351. These specifications are typical at 25 °C unless otherwise stated. The operating temperature range is 0 to 50 °C.

System Requirements

Personal computer with at least one free x8 or x16 PCI Express slot, 4 GB RAM, 100 MB of free hard disk space,

PCI Express revision	1.0a or higher
Transceiver speed	2.5 Gbps
Number of lanes	8
Compatibility - mechanical	x8 and x16 slots
Compatibility - electrical	x1, x4, x8 and x16 slots

Power Requirements

+12V	1.5 A, typical
+3.3V	1.0 A, typical

Physical

Size	Single slot, half-length PCI card (4.2 inches x 6.5 inches)
Weight	500 g

I/O Connectors

ECLK, CH A, CH B	SMA female connector
TRIG IN, AUX I/O	BNC female connectors

Environmental

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

Acquisition System

Resolution	12 bits
Bandwidth (-3dB)	
DC-coupled, 50 Ω	DC - 500 MHz
Bandwidth flatness:	± 1 dB, from DC to 50 MHz with DC coupling
Number of channels	2 simultaneously sampled
Maximum Sample Rate	500 MS/s single shot (internal clock) 500 MS/s single shot (external clock)
Minimum Sample Rate	1 KS/s single shot (internal clock) 1 MS/s single shot (Fast External Clock)
Full Scale Input ranges	± 400 mV fixed
DC accuracy	$\pm 2\%$ of full scale in all input ranges
Input coupling	DC fixed
Input impedance	50 Ω fixed
Input protection	
50 Ω	± 5 V (DC + peak AC for CH A, CH B and EXT only without external attenuation)

Acquisition Memory System

Memory Size	128 MegaSamples, 1 GigaSamples or 2 GigaSamples. Shared equally between the two channels in dual channel mode.
Record Length	Software selectable with 64-point resolution. Record length must be a minimum of 256 points. There is no upper limit on the maximum record length.
Number of Records	1 to 1000 for single-port memory operation. 1 to infinite for dual port memory operation.
Pre-trigger depth	From 0 to (Record Length - 256)
Post-trigger depth	Record Length - Pre-Trigger Depth

Timebase System

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

Dynamic Parameters

Typical values measured using a randomly selected ATS9351 in 400 mV range. Input was provided by an Agilent 33522A signal generator, followed by a 9-pole, 5 MHz band-pass filter (TTE Q36T-5M-500K-50-720BMF). Input frequency was set at 4.9 MHz and output amplitude was 940 mV p-p.

SNR	61.9 dB
SINAD	61.17 dB
THD	-69.28 dB
SFDR	-75.12 dB

Note that these measurements were made using raw data: no signal averaging was used to artificially improve the results.

Further 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	400 mV _{p-p} to 3 Volt _{p-p} sine or square wave
Input impedance	50Ω
Input Coupling	AC
Maximum frequency	
Fast External Clock:	500 MHz with 50% ±5% duty cycle
Slow External Clock:	60 MHz with minimum positive or negative pulse width of 8 ns
10 MHz Clock Reference:	10.1 MHz
Minimum frequency	
Fast External Clock:	2 MHz
Slow External Clock:	DC
10 MHz Clock Reference:	9.9 MHz
Decimation factor	Software selectable from 1 to 100,000 Fixed to 1 for Slow External Clock
Sampling Edge	Rising or Falling, software selectable
Sample Rates Available With 10 MHz Clock Reference:	500 MS/s
	Other sample rates may be obtained by decimating the 1 GHz clock generated by the on-board PLL
	Note that the accuracy and stability of these sampling frequencies is dependent on the accuracy and stability of the 10 MHz Clock Reference input supplied by the user

Triggering System

Mode	Edge triggering with fixed hysteresis
Number of Trigger Engines	2
Trigger Engine Combination	OR, AND, XOR, software selectable
Trigger Engine Source	CH A, CH B, EXT, 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	±10%, typical, of full-scale input range of the selected trigger source

Bandwidth	200 MHz
Trigger Delay	Software selectable from 0 to 9,999,999 sampling clock cycles
Trigger Timeout	Software selectable with a 10 us resolution. Maximum settable value is 3,600 seconds. Can also be disabled to wait indefinitely for a trigger event

EXT (External Trigger) Input

Input impedance	10 K Ω in parallel with 30pF \pm 10pF or 50 Ω , software selectable
Bandwidth (-3dB)	
DC-coupled	DC - 200 MHz
AC-coupled	100 KHz - 200 MHz
Input range	\pm 3.3V
DC accuracy	\pm 10% of full-scale input
Input protection	\pm 5V (DC + peak AC without external attenuation)
Coupling	DC, software selectable

Auxiliary I/O (AUX I/O)

Signal Direction	Input or Output, software selectable 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 rising edge of sampling clock
Input	
Amplitude:	5 Volt TTL or 3.3 Volt TTL

Certification and Compliances

CE Mark Compliance

Materials Supplied

One ATS9351 Digitizer

One ATS9351 Install Disk on USB drive

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.

Model	Chipset	Slot	O/S	Throughput
ASUS P6T7	X58	PCIe x16	All	1.6 GB/s
Intel S5000PSL	Intel 5000P	PCIe x8	Win XP 32-bit	1.6 GB/s
Intel S5000PSL	Intel 5000P	PCIe x8	Win XP 64-bit	1.6 GB/s
Intel S5000PSL	Intel 5000P	PCIe x8	Vista 32-bit	1.6 GB/s
Intel S5000PSL	Intel 5000P	PCIe x8	Vista 64-bit	1.6 GB/s
Tyan S2915-E	nVIDIA NPF3600 + NPF 3050	PCIe x8	Win XP 64-bit	1.6 GB/s
Dell T3400	Intel 975 Express	PCI e x4	Win XP 32-bit	800 MB/s
Dell T7400	Intel 5400	PCIe x8	Win XP 64-bit	1.6 GB/s

Dell T7400	Intel 5400	PCIe x8	Vista 64-bit	1.6 GB/s
SuperMicro X7DB3	Intel 5000P	PCIe x8	Win XP 32-bit	1.6 GB/s
Intel DG965RY	Intel 965	PCIe x16	Win XP 32-bit	840 MB/s



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