AlazarTech

ATS9625 User Manual

16 Bit, 250 MS/s
Waveform Digitizer for PCI Express Bus

Written for Hardware Version 1.3
June 2016 Edition
Part Number: 9360-USR-1

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Owned by: _____

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*

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 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.

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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*.

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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.

Table of Contents

Chapter 1 - Introduction

This chapter describes the ATS9625 and lists additional equipment.

About Your ATS9625

Thank you for your purchase of an ATS9625. This PCI Express (PCIe x8) based waveform digitizer has the following features:

- Two 16-bit resolution analog input channels
- Real-time sampling rate of 250 MS/s to 1 KS/s with internal clock and 250 MS/s to 50 MS/s with external clock
- User programmable Stratix III FPGA
- On-board acquisition memory buffer of 2 Gigasamples (4 Gigabytes)
- Streaming of acquired data to PC host memory at 1.6 GB/s (exact rate is motherboard dependent)
- AC coupled inputs (for dc coupling, see ATS9626)
- 50 Ω input impedance
- 1 MHz ~150 MHz analog input bandwidth
- Half length PCI Express (8 lane) card
- External Trigger LVTTL input
- Two front panel Auxiliary I/Os
- 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 ATS9625 digitizers follow industry-standard Plug and Play specifications on all platforms and offer seamless integration with compliant systems.

Detailed specifications of the ATS9625 digitizers are listed in Appendix A, Specifications.

Acquiring Data with Your ATS9625

You can acquire data either programmatically by writing an application for your ATS9625 or interactively with the AlazarDSO software.

If you want to integrate the ATS9625 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.

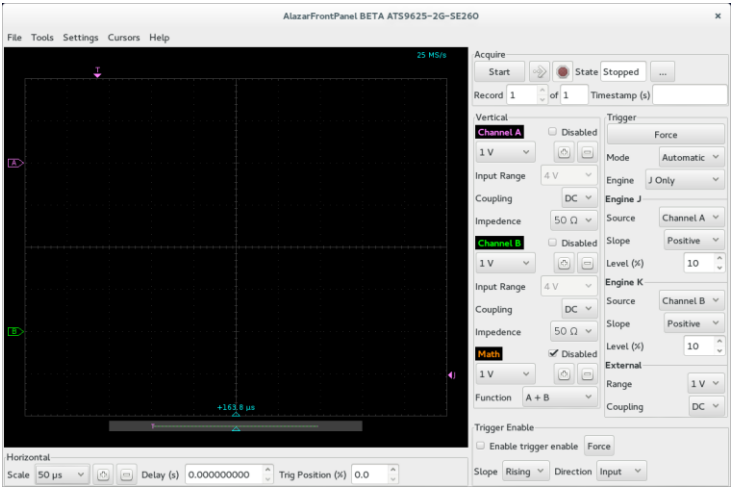
- Windows operating systems supported are Windows 8, 7, Windows Vista and Windows XP, Windows Both 32 bit and 64 bit operating systems.
- The Linux CentOS distribution is also supported, which is 100% compatible with Red Hat Entreprise Linux. Drivers are compiled agains all RHEL versions that are in Production 1 phase (RHEL 6 and 7 as of 09/04/15).
- For other Linux distributions, contact AlazarTech and a driver will be compiled for you.

For using a programming language to acquire data from your ATS9625, you must purchase the ATS-SDK package.

Interactively Controlling your ATS9625

The AlazarDSO oscilloscope emulation software for Windows allows you to interactively control your ATS9625 as you would a desktop oscilloscope.

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



ATS-SDK API

The ATS-SDK API is used for programming the ATS9625 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..

Optional Upgrades

AlazarTech offers the following upgrades and accessories for use with your ATS9625 digitizer:

- ATS9625: Master/Slave SyncBoard 2 position
- ATS9625: Master/Slave SyncBoard 4 position
- AlazarDSO – Stream To Disk Module

Chapter 2 - Installation and Configuration

This chapter describes how to unpack, install, and configure your ATS9625.

What You Need to Get Started

To set up and use your ATS9625, you will need the following:

- One or more ATS9625 digitizers

- ATS9625 Installation Software on USB Disk

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 ATS9625

There are four main steps involved in installation:

1. Physically install the digitizer(s) and SyncBoard, if any, in your computer.
2. Install ATS9625 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 ATS9625

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 ATS9625 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 ATS9625 digitizer in one of the free PCI Express slots. For best noise performance, leave as much room as possible between your ATS9625 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, ATS9625 is not guaranteed to operate within the specifications listed elsewhere in this manual.

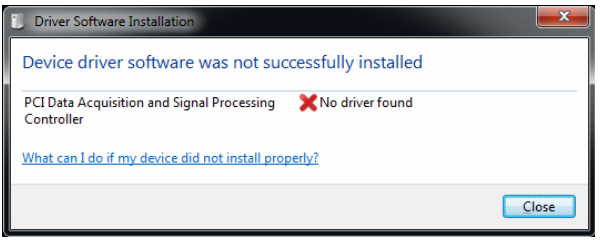
⚠ Some motherboards may have a 16-lane connector, but only one or four of the lanes is connected to the motherboard chipset. Motherboard manufacturers refer to this as "Mechanically 16-lane, electrically 1 lane". ATS9625 is fully compatible with such motherboards, but the data throughput across PCI Express bus will be limited by the number of lanes.

2. Install ATS9625 software driver

The following instructions guide you through the process of installing the ATS9625 in a computer running Windows 8, 7, Vista or Windows XP 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 ATS9625 device driver is not found, Windows will display the following dialog box

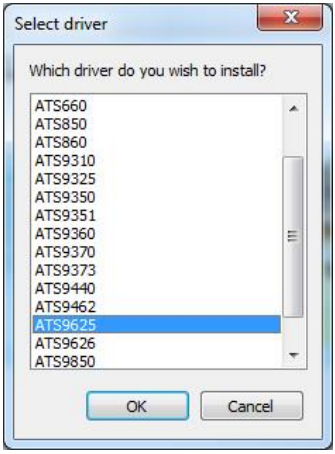


Click **Close**.

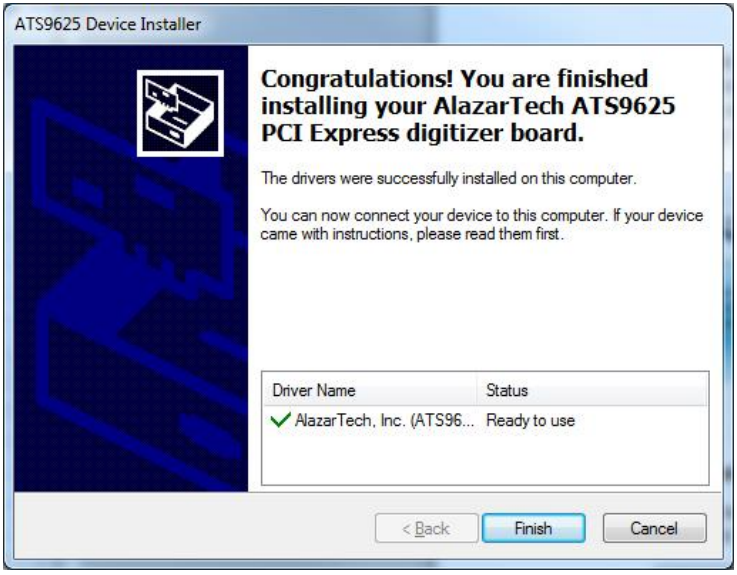
b) Insert the installation disk that is supplied on a USB flash drive. If It does not auto-run, manually run the Autorun.exe program on the USB flash drive. The following splash schreen will be displayed.

Click **Install Driver**.

c) The following screen will appear. Select ATS9625 and click OK

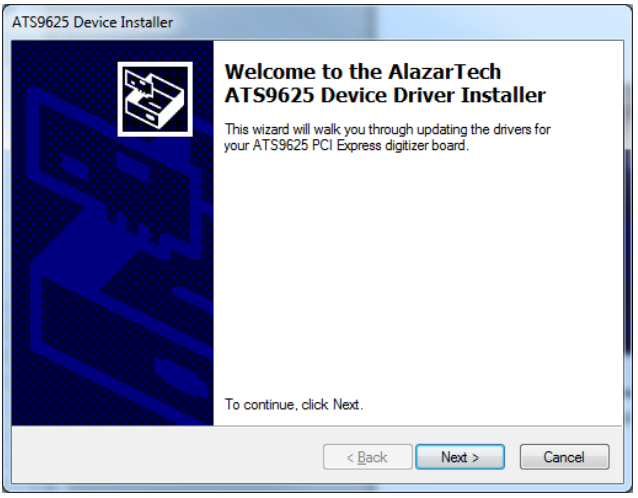


d) Windows will display the Welcome to the AlazarTech ATS9625 Device Driver Installer.



e) 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.'

f) A dialog box will be displayed showing the progress of installation of ATS9625 driver files in the operating system driver store. The following final screen will confirm that the driver has been insalled.



Now your ATS9625 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 ATS9625 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 software

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

If, for any reason, installation does not start automatically, run the ATS-SDK-Setup-7.0.0.exe.

Follow the instructions on the screen.

Note that you must have already installed the ATS9625 drivers for any of the sample programs included with the ATS-SDK to work properly.

Installing the ATS9625 in a Linux System

ATS9625 ships with the following software packages, that can be installed with the standard package manager of your distribution:

1. A driver package, named after the board model. It needs to be installed on a system running the exact same kernel version it was compiled with.
2. A library package. It contains the shared library that the applications using the digitizers link against.
3. A package containing Alazar Front Panel, a virtual oscilloscope application that allows you to use most of the features of the boards without programming.

The ATS-SDK product contains an extra software package 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

To install an ATS9625 on your Linux system, follow the next steps:

1. Connect one or several ATS9625 in your computer
2. Optionnaly connect the SyncBoard(s)
3. Start your computer, and install all the software packages provided with your ATS9625. 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.

Updating ATS9625 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 ATS9625 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.

Chapter 1 Download the latest driver from AlazarTech's web site:
www.alazartech.com/support/downloads.htm

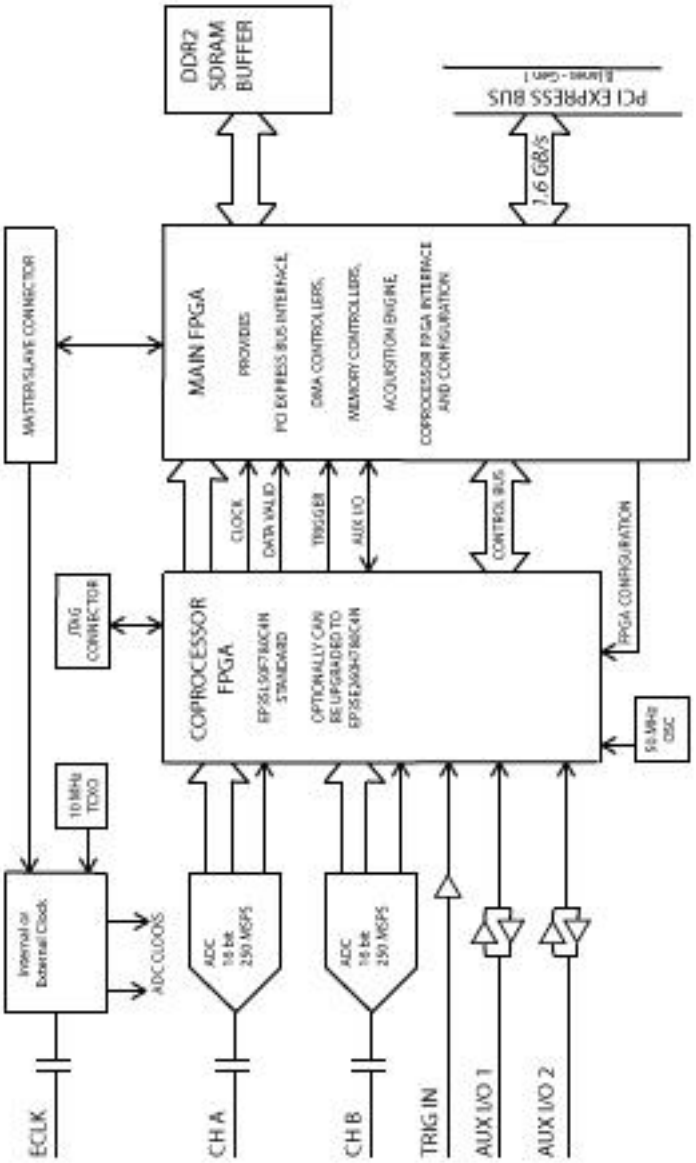
Chapter 2 ⚠ Unzip the downloaded file to a local folder

Chapter 3 Run the resulting installation file (*.exe extension). For example, the installation file for driver version 5.9.23 is called **ATS9625_Driver_V5.9.23.exe**, and follow the instructions.

Chapter 3 - Hardware Overview

This chapter includes an overview of the ATS9625, explains the operation of each functional unit making up your ATS9625, and describes the signal connections.

Following is a high-level block diagram of ATS9625.


DDR2 SDRAM BUFFER
PCI EXPRESS BUS
1.6 GB/s
MASTER/SLAVE CONNECTOR
MAIN FPGA
PROVIDES
PCI EXPRESS BUS INTERFACE
DMA CONTROLLERS,
MEMORY CONTROLLERS,
ACQUISITION ENGINE,
COPROCESSOR FPGA INTERFACE AND CONFIGURATION
CLOCK
DATA VALID
TRIGGER
AUX I/O
CONTROL BUS
FPGA CONFIGURATION
JTAG CONNECTOR
COPROCESSOR FPGA
EP3SL50F780C4N STANDARD
OPTIONALLY CAN BE UPGRADED TO EP3SE260H780C4N
50 MHz OSC
10 MHz TCXO
Internal or External Clock
ADC CLOCKS
ADC 10 bit 250 MSPS
ADC 10 bit 250 MSPS
ECLK
CH A
CH B
TRIG IN
AUX I/O 1
AUX I/O 2

Input Connectors

ATS9625 digitizers have the following connectors on the front panel:

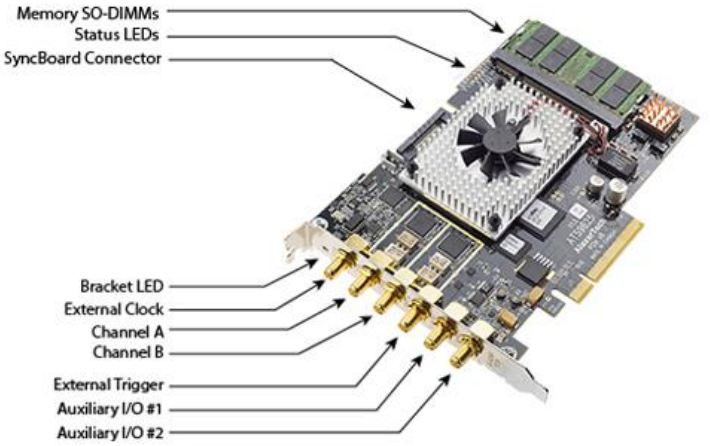


Figure 1 - ATS9625 Overview

Signal Connections

ECLK
This is a female SMA connector that is used for supplying an external clock. See the chapter on External Clock for more details.

CH A
This is a female SMA connector that is used for supplying the analog signal which will be digitized as Channel A. See the chapter on Analog Inputs for more details.

CH B
This is a female SMA connector that is used for supplying the analog signal which will be digitized as Channel B. See the chapter on Analog Inputs for more details.

TRIG IN
This is a female SMA connector that is used for supplying a digital (LVTTL) external trigger signal. See the chapter on External Trigger for more details.

AUX 1
This is a female SMA connector that is used for supplying a digital (LVTTL) signal called Auxiliary I/O 1. Note that this signal is bidirectional. See the section on Auxialiary I/Os for more details.

AUX 2
This is a female SMA connector that is used for supplying a digital (LVTTL) signal called Auxiliary I/O 2. Note that this signal is bidirectional. See the section on Auxialiary I/Os for more details.

Coprocessor FPGA

As shown in the ATS9625 block diagram, all signals to and from the front panel pass through the Coprocessor FPGA.

The default firmware loaded by the device driver is a “pass-through” FPGA. This way, users who do not wish to customize the FPGA but do need the fast 16 bit ADC capability of the ATS9625 can use the product straight out of the box.

Coprocessor is a Stratix III FPGA from Altera. There are two FPGA sizes supported:

- EP3SL50F780C4N

  or

- EP3SE260H780C4N

To design a custom Coprocessor FPGA, you must purchase ATS9625 FPGA Development Kit (ATS-FDK).

For more information on ATS-FDK, please see the FPGA Development Kit Manual on the ATS9625 product page:

http://www.alazartech.com/products/ats9625.htm

Analog Inputs

The two analog input channels (labeled CH A and CH B) 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 ATS9625 by attaching the probe's ground clip to the signal ground.

Both analog inputs are ac-coupled with a low frequency cutoff at approximately 1 MHz. The frequency response of the inputs is as shown below:

As such, lower input frequencies cannot be measured using ATS9625. If you try to inject a lower frequency signal, e.g. 10 KHz sine wave or dc level, it will be severely if not totally attenuated. If your application requires you to be able to measure lower frequency signals, you should use ATS9626 waveform digitizer that features dc-coupled inputs.

The input gain is also fixed on ATS9625. This results in a fixed full scale input range of +/- 1.25V, or 2.5Vp-p.

Also note that the input impedance of 50Ω is a dynamic impedance, not resistive.

Monolithic 16-bit ADC
ATS9625 uses two monolithic analog-to-digital converters with a maximum conversion rate of 250 MS/s at 16 bit resolution.

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

Multiple Record Acquisition
The ATS9625 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 ATS9625 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.

External Trigger

ATS9625 allows you to supply an TRIG IN (also known as External Trigger) signal for triggering purposes.

External Trigger must an LVTTL digital signal, i.e. 0 to 3.3V TTL signal. Minimum pulse height requirement is 2.0 Volts. Input impedance of this input is 10 KΩ.

Analog signals and smaller amplitude digital signals will not be detected as trigger events.

User can select between rising edge and falling edge of this signal as the trigger event.

It should be noted that the TRIG IN signal passes through the Coprocessor FPGA. This description of TRIG IN applies to the default Coprocessor FPGA shipped with ATS9625 drivers. A custom Coprocessor FPGA can completely change the functionality of this signal.

Auxiliary I/O

There are two Auxiliary I/Os available on ATS9625.

Both I/Os are 5V signals. Minimum input pulse height is 2.0V.

By default, AUX1 is a Trigger output and AUX2 is unused.

AUX1 can be programmed to output any of the following signals:

- Trigger Output
- Pacer clock
- Digitizer Armed output
- ADC CLK DIV 4 output
- INITCLK output
- End of Acquisition Pulse
- Software Controlled output

AUX1 can alternatively be programmed as any of the following inputs:

- Trigger Enable
- Reset Timestamp
- Input to a software register

Note that AUX1 cannot simultaneously be an input and an output.

AUX2 is fixed as a Trigger output.

It should be noted that both AUX I/O signals pass through the Coprocessor FPGA. This description of AUX I/O applies to the default Coprocessor FPGA shipped with ATS9625 drivers. A custom Coprocessor FPGA can completely change the functionality of these signals.

Calibration

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

All ATS9625 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 ATS9625 digitizer.

Externally recalibrate the ATS9625 when this calibration interval has expired.

This requires three very simple steps:

1. Verify whether or not ATS9625 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 ATS9625 is within specifications

Calibration Verification procedures are available to all registered users of ATS9625 as part of AlazarDSO software.

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

External Clock

ATS9625 allows you to bypass the on-board clock oscillator and supply your 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 ATS9625:

- 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 50 MHz to 250 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 50 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.

External Clock must be a sine wave or square wave signal with amplitude in the range of 100 mV_{p-p} to 1 V_{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 ATS9625 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 250 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 4 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 awith a minimum pulse height requirement of 2.0 Volts for guaranteed operation. Signals with smaller amplitudes may not be detected and may result in corrupted data or failed triggering.

10 MHz Clock Reference
ATS9625 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 mV_{p-p} to 1 V_{p-p}.

It should be noted that the 10 MHz reference produces a 250 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 ATS9625 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.

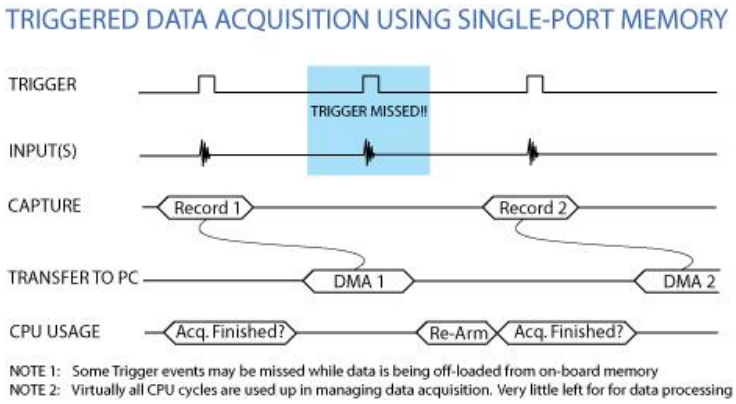
Furthermore, you may not be able to get software drivers for the selected RTOS for all the hardware components you need for your system.

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.

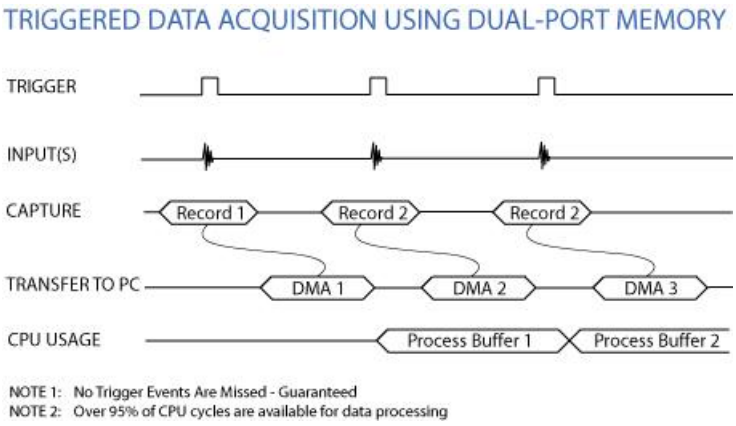
Dual Port Memory

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.



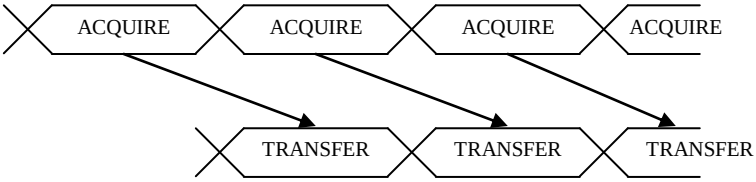
ATS9625 solves this problem by providing dual-port memory that can act as a very deep FIFO and an advanced dual-DMA engine that can stream data to PC host memory at up to
1.4 GB/s (exact rate is motherboard dependent).



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.

ATS9625'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 ATS9625 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. ATS9625 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 ATS9625. 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, 256 MB RAM, 20 MB of free hard disk space,

PCI Express revision	1.0a or higher
Transceiver speed	2.5 Gbps
Number of lanes	4 or 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	SMA female connector
CH A, CH B, TRIG IN, AUX I/O	BNC female connectors

Environmental

Operating temperature	0 to 55 ^{o} C
Storage temperature	-20 to 70 ^{o} C
Relative humidity	5 to 95%, non-condensing

Acquisition System

Resolution	12 bits
Bandwidth (-3dB)	
DC-coupled, 50Ω	DC - 500 MHz
AC-coupled, 50Ω	100KHz - 500 MHz
Bandwidth flatness:	± 1dB, from DC to 50 MHz with DC coupling ± 1dB, from 200 KHz to 50 MHz with AC 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) 2 MS/s single shot (Fast External Clock)
Full Scale Input ranges	
50 Ω:	±200mV, ±400mV, ±800mV, ±1V, ±2V and ±4V, software selectable
DC accuracy	±2% of full scale in all input ranges
Input coupling	AC or DC, software selectable
Input impedance	50Ω fixed
Input protection	
50Ω	±5V (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
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	Software selectable from a minimum of 1 to a maximum of infinite number of records
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 ATS9625 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	54.3 dB
SINAD	53.9 dB
THD	-64.4 dB
SFDR	-72.03 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	LVTTL levels or sine wave with amplitude between 100 mV_{p-p} and 1 $Volt_{p-p}$
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 Referece 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 KΩ in parallel with 30pF ±10pF or 50Ω, software selectable
Bandwidth (-3dB)	
DC-coupled	DC - 200 MHz
AC-coupled	100 KHz - 200 MHz
Input range	±3.3V
DC accuracy	±10% of full-scale input
Input protection	±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 ATS9625 Digitizer

One ATS9625 Install Disk (USB drive)

Supported Linux Distributions

AlazarTech supports CentOS and Red Hat Entreprise Linux distributions. All versions that are in production phase 1 are supported (RHEL 6 and RHEL 7 as of 10/04/15)

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 P9X79 Pro	X79	PCIe x16	All	1.7 GB/s
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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