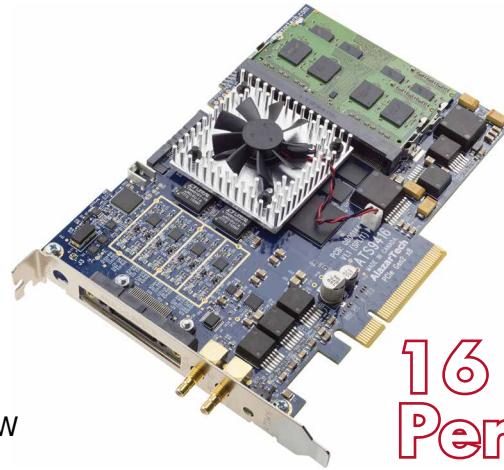


- 16 analog channels per card
- Sample rate of 100 MS/s per channel
- 14 bit vertical resolution
- PCI Express Gen 2 interface
- 3.5 GB/s sustained throughput
- Up to 4 GigaSample dual-port memory
- Continuous streaming mode
- Asynchronous DMA device driver
- AlazarDSO oscilloscope software
- Software Development Kit supports C/C++, C#, MATLAB, Python and LabVIEW
- Linux driver available



16 Inputs Per Card

Product	Bus	Operating System	Channels	Sampling Rate	Bandwidth	Memory Per Channel	Resolution
ATS9416	PCIe Gen2 x8	Win10/8/7/Vista, CentOS 6.x~7.x 32bit/64 bit	16	100 MS/s to 100 KS/s	65 MHz Optional 100 MHz	Up to 4 Gig in single channel mode	14 bits

Overview

ATS9416 is an 8-lane PCI Express Gen 2, 16-channel, high speed, 14 bit, 100 MS/s waveform digitizer card capable of streaming acquired data to PC memory at rates up to 3.5 GB/s or storing it in its deep on-board dual-port acquisition memory buffer of up to 4 Gigasamples.

Each ATS9416 board has 16 analog to digital converter (ADC) chips that are clocked simultaneously using a low jitter VCO to provide absolute synchronization.

A high density RF connector is used to increase the I/O density on the back-panel of ATS9416.

Up to four ATS9416 boards can be configured as a Master/Slave system to create a simultaneous sampling system of up to 64 input channels.

Users can capture data from one trigger or a burst of triggers. Users can also stream very large datasets continuously to PC memory or hard disk.

ATS9416 is supplied with AlazarDSO software that lets the user get started immediately without having to go through a software development process.

Users who need to integrate the ATS9416 in their own program can purchase a software development kit, ATS-SDK, for C/C++, C#, MATLAB, Python and LabVIEW for both Windows and Linux operating systems.

All of this advanced functionality is packaged in a low power, half-length PCI Express card.

Applications

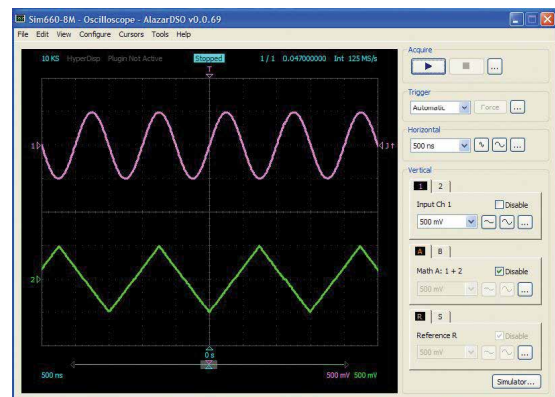
Fiber Sensing

Multi-Channel RF Recording

Terabyte Storage Oscilloscope

High Resolution Oscilloscope

Spectroscopy





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PCI Express Bus Interface

ATS9416 interfaces to the host computer using an 8-lane PCI Express bus. Each lane operates at 5 Gbps (Gen 2). By definition, ATS9416 is also compatible with PCI Express Gen 1 and Gen 3.

According to PCIe specification, an 8-lane board can be plugged into any 8-lane or 16-lane slot, but not into a 4-lane or 1-lane slot. As such, ATS9416 requires at least one free 8-lane or 16-lane slot on the motherboard.

The physical and logical PCIe x8 interface is provided by an on-board FPGA, which also integrates acquisition control functions, memory management functions and acquisition datapath. This very high degree of integration maximizes product reliability.

AlazarTech's 3.5 GB/s bus throughput benchmark was done on an ASUS X99 Deluxe motherboard based on the X99 chipset.

Other motherboards, such as Asus P9X79 and AS-ROCK X79 Extreme 11 produced similar results. Older machines, such as the Dell T7400 also supported 3.5 GB/s.

Some multi-processor server boards that used SandyBridge CPUs were found to behave very poorly under Windows. The same server boards with the more modern IvyBridge CPUs behaved normally and provided the expected 3.5 GB/s throughput. AlazarTech recommends that customers not use the older SandyBridge CPUs in multi-processor server boards.

Users must always be wary of throughput specifications from manufacturers of waveform digitizers. Some unscrupulous manufacturers tend to specify the raw, burst-mode throughput of the bus. AlazarTech, on the other hand, specifies the benchmarked sustained throughput. To achieve such high throughput, a great deal of proprietary memory management logic and kernel mode drivers have been designed.

High Density Input Connector

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

More information on this connector can be found at http://www.samtec.com/ftppub/pdf/qss_ra.pdf

All 16 analog input channels pass through this connector. External Trigger, AUX I/O and External clock signals use their own coaxial connectors. This was done to minimize crosstalk between these signals and the 16 analog inputs.

AlazarTech can supply a number of different cables that mate with this connector. Alternatively, customers can order their own cables from SAMTEC.

ATS9416 CONNECTOR PINOUT

Pin	Signal	Pin	Signal
1	Not Connected	2	AGND
3	AGND	4	CH 16
5	CH 13	6	AGND
7	AGND	8	AGND
9	AGND	10	CH 14
11	CH 15	12	AGND
13	AGND	14	AGND
15	AGND	16	CH 12
17	CH 9	18	AGND
19	AGND	20	AGND
21	AGND	22	CH 10
23	CH 11	24	AGND
25	AGND	26	AGND
27	AGND	28	CH 8
29	CH 5	30	AGND
31	AGND	32	AGND
33	AGND	34	CH 6
35	CH 7	36	AGND
37	AGND	38	AGND
39	AGND	40	CH 4
41	CH 1	42	AGND
43	AGND	44	AGND
45	AGND	46	CH 2
47	CH 3	48	AGND
49	AGND	50	Not Connected
SHIELD		AGND	

RF cables

The most popular cable (sold separately) is one that terminates to 16 BNC plugs. This cable is called QSS-BNC16 cable.

If customers want to design an identical QSS-025-01-L-D-RA-MTI connector on their circuit board, it is also possible to purchase a cable that can mate the two QSS connectors. This cable is called QSS-QSS cable.

Analog Input

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

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



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Within the above-mentioned constraint, users can select a full scale input range of $\pm 1V$ or ± 500 mV.

Input impedance of all channels is fixed at 50Ω . Input coupling of all channels is fixed at DC coupling .

Acquisition System

ATS9416 PCI Express digitizer board uses two state of the art octal (x8) 100 MSPS, 14-bit ADCs to digitize the input signals. This means there are a total of 16 individual A/D converters, each running at 100 MS/s.

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

The real-time sampling rate ranges from 100 MS/s down to 100 KS/s for internal clock and 5 MS/s for external clock.

An acquisition can consist of multiple records, with each record being captured as a result of one trigger event. A record can contain both pre-trigger and post-trigger data.

Infinite number of triggers can be captured by ATS9416, when it is operating using dual-port memory.

In between the multiple triggers being captured, the acquisition system is re-armed by the hardware within 64 sampling clock cycles.

This mode of capture, sometimes referred to as Multiple Record, is very useful for capturing data in applications with a very rapid or unpredictable trigger rate. Examples of such applications include medical imaging, ultrasonic testing, OCT and spectroscopy.

On-Board Acquisition Memory

ATS9416 supports on-board memory buffer of 4 Gigasamples. Note that one sample is stored as two bytes, so 4 Gigasample means there is 8 GByte memory on-board.

Acquisition memory can be divided equally between the selected input channels.

For example, ATS9416 provides 4 Gigasamples of on-board memory when sampling in one-channel mode. In two-channel mode, it provides 2 Gigasamples per channel of on-board memory. In four-channel mode, it provides 1 Gigasamples per channel of on-board memory and so on.

When operated as dual port memory, the on-board memory acts as a very deep FIFO between the Analog to Digital converters and PCI Express bus, allowing very fast sustained data transfers across the bus, even if the operating system or another motherboard resource temporarily interrupts DMA transfers.

Maximum Sustained Transfer Rate

PCI Express support on different motherboards is not always the same, resulting in significantly different sustained data transfer rates.

For example, it is possible that a motherboard may have an x8 PCI Express connector, but only one PCIe lane in connected on the motherboard. Motherboard documentation will refer to such a slot as "x8 mechanical, x1 electrical". In such a system, the maximum data throughput may be as low as 200 MB/s.

ATS9416 users can quickly determine the maximum sustained transfer rate for their motherboard by inserting their card in a PCIe slot and running the Tools: Benchmark: Bus tool provided in AlazarDSO software.

ATS9416, which is equipped with dual-port on-board memory, will be able to achieve this maximum sustained transfer rate.

Recommended Motherboards

Many different types of motherboards have been benchmarked by AlazarTech. The best performance is provided by motherboards that use the Intel x99 chipset. The motherboard that has consistently given the best throughput results (as high as 3.5 GB/s) has been te ASUS X99 Deluxe.

Other motherboards. such as Asus P9X79 and AS-ROCK X79 Extereme 11 produced similar results. Older machines, such as the Dell T7400 also supported 3.5 GB/s.

Some multi-processor server boards that used Sandy-Bridge CPUs were found to behave very poorly under Windows and Linux. The same server boards with the more modern IvyBridge CPUs behaved normally and provided the expected 3.5 GB/s throughput. AlazarTech recommends that customers not use the older SandyBridge CPUs in multi-processor server boards.

No Pre-Trigger (NPT) AutoDMA

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

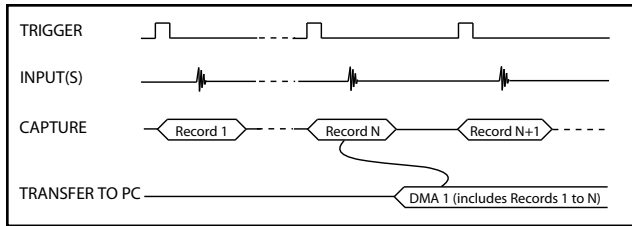
NPT AutoDMA is designed specifically for these applications. By only storing post-trigger data, the memory bandwidth is optimized and the entire on-board memory acts like a very deep FIFO.

More recently, some customer applications have required a limited amount of pre-trigger data to be available even in NPT AutoDMA. This capability has been added to ATS9416 and now it is possible to acquire up to 4096 points of pre-trigger data in NPT mode.



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Note that a DMA is not started until RecordsPerBuffer number of records (triggers) have been acquired and written to the on-board memory.

NPT AutoDMA buffers support footers, so it is possible to get a 40-bit timestamp as well as other information about the record.

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

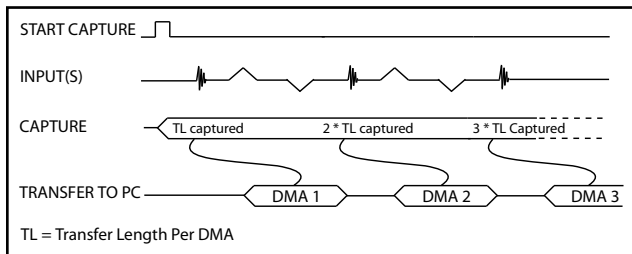
NPT AutoDMA can easily acquire data to PC host memory at the maximum sustained transfer rate of the motherboard without causing an overflow.

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

Continuous AutoDMA

Continuous AutoDMA is also known as data streaming mode.

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



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

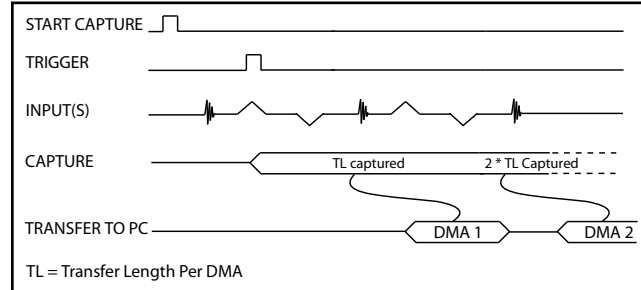
A BUFFER_OVERFLOW flag is asserted only if the entire on-board memory is used up.

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

Continuous AutoDMA can easily acquire data to PC host memory at the maximum sustained transfer rate of the motherboard without causing an overflow. This is the recommended mode for very long signal recording.

Triggered Streaming AutoDMA

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



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

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

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

Triggered Streaming AutoDMA can easily acquire data to PC host memory at the maximum sustained transfer rate of the motherboard without causing an overflow. This is the recommended mode for RF signal recording that has to be started at a specific time, e.g. based on a GPS pulse.

Master/Slave Systems

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



SyncBoard-9416 is a mezzanine board that connects to the Master/Slave connector along the top edge of the ATS9416 and sits parallel to the motherboard. For additional robustness, users can secure the SyncBoard-9416 to a bracket mounted on each of the ATS9416 boards.

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

SyncBoards with the -W suffix provide 2-slot spacing between ATS9416 cards to support some of the newer motherboards that space out the on-board x8 or x16 slots by two slots. The -W SyncBoards are also a better solution from thermal point of view, as there is better air flow with 2-slot spacing.



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The 2X and 2X-W models allow a 2-board Master/Slave system; the 3X-W model allows a 2 or 3-slot Master/Slave system; and the 4X and 4X-W models allow 2, 3 or 4 board Master/Slave systems.

The Master board's clock, trigger and initialization signals are copied by the SyncBoard-9416 and supplied to all the Slave boards. This guarantees complete synchronization between the Master board and all Slave boards.

It should be noted that SyncBoard-9416 does not use a PLL-based clock buffer, allowing the use of variable frequency clocks in Master/Slave configuration.

A Master/Slave system samples all inputs simultaneously, triggers all boards simultaneously and also starts the acquisition simultaneously on all board (on the same clock edge).

For optimal trigger accuracy, only the Master board is allowed to trigger the acquisition system.

Asynchronous DMA Driver

The various AutoDMA schemes discussed above provide hardware support for optimal data transfer. However, a corresponding high performance software mechanism is also required to make sure sustained data transfer can be achieved.

This proprietary software mechanism is called Async DMA (short for Asynchronous DMA).

A number of data buffers are posted by the application software. Once a data buffer is filled, i.e. a DMA has been completed, ATS9416 hardware generates an interrupt, causing an event message to be sent to the application so it can start consuming data. Once the data has been consumed, the application can post the data buffer back on the queue. This can go on indefinitely.

One of the great advantages of Async DMA is that almost 95% of CPU cycles are available for data processing, as all DMA arming is done on an event-driven basis.

To the best of our knowledge, no other supplier of waveform digitizers provides asynchronous software drivers. Their synchronous drivers force the CPU to manage data acquisition, thereby slowing down the overall data acquisition process.

Triggering

ATS9416 is equipped with sophisticated digital triggering options, such as programmable trigger thresholds and slope on any of the input channels or the External Trigger input.

While most oscilloscopes offer only one trigger engine, ATS9416 offers two trigger engines (called Engines X and Y).

The user can specify the number of records to capture in an acquisition, the length of each record and the amount of pre-trigger data.

A programmable trigger delay can also be set by the user. This is very useful for capturing the signal of interest in a pulse-echo application, such as ultrasound, radar, lidar etc.

External Trigger Input

The external trigger input on the ATS9416 is labeled TRIG IN.

External trigger can either be a $\pm 3V$ analog input with 50 Ohm impedance, or a digital TTL input with 2 kiloOhm impedance. This choice of External Trigger input range is software selectable.

Timebase

ATS9416 timebase can be controlled either by on-board low-jitter VCO or by optional Fast External Clock or by an external 10 MHz REF IN.

On-board low-jitter VCO uses an on-board 10 MHz TCXO as a reference clock.

Fast External Clock

While the ATS9416 features low jitter VCO and a 10 MHz TCXO as the source of the timebase system, there may be occasions when digitizing has to be synchronized to an external clock source.

ATS9416 External Clock option provides an SMA input for an external clock signal, which can be a sine wave or LVTTTL signal.

Input impedance for the External Clock input is fixed at 50 Ω . External clock input is always ac-coupled.

A new sample is taken by the on-board ADCs for each rising edge of this Fast External Clock signal.

In order to satisfy the clocking requirements of the ADC chips being used, Fast External Clock frequency must always be higher than 5 MHz and lower than 100 MHz.

10 MHz Reference Clock Input

It is possible to generate the sampling clock based on an external 10 MHz reference input. This is useful for RF systems that use a common 10 MHz reference clock.

ATS9416 uses an on-board low-jitter VCO to generate the sampling clock used by the ADC. This sampling clock can be set to any value between 5 MHz and 100 MHz with a 1 MHz resolution.

Auxiliary (AUX) I/O

ATS9416 provides an AUX (Auxiliary) I/O signal that can be used to input or output various signals.

When configured as a Trigger Output, AUX connec-



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tor outputs a 5 Volt TTL signal synchronous to the ATS9416 Trigger signal, allowing users to synchronize their test systems to the ATS9416 Trigger.

When combined with the Trigger Delay feature of the ATS9416, this option is ideal for ultrasonic and other pulse-echo imaging applications.

AUX connector can also be used as a Trigger Enable Input that can be used for frame capture applications.

Calibration

Every ATS9416 digitizer is factory calibrated to NIST-traceable standards. To recalibrate an ATS9416, the digitizer must either be shipped back to the factory or a qualified metrology lab.

On-Board Monitoring

Adding to the reliability offered by ATS9416 are the on-board diagnostic circuits that constantly monitor over 20 different voltages, currents and temperatures. LED alarms are activated if any of the values surpasses the limits.

AlazarDSO Software

ATS9416 is supplied with the powerful AlazarDSO software that allows the user to setup the acquisition hardware and capture, display and archive the signals.

An optional Stream-To-Disk add-on module for AlazarDSO allows users to stream data to hard disk. For the fastest possible streaming, the hard disks have to be used in a RAID 0 configuration.

Users are also able to write their own Plug-In modules. A Plug-In is a DLL that is called each time AlazarDSO receives a data buffer. Many different data processing and control functions can be built into a Plug-In. Examples include Averaging, Co-Adding, controlling acquisition based on an external GPS module etc.

AlazarDSO software also includes powerful tools for benchmarking the computer bus and disk drive.

Software Development Kits

AlazarTech provides easy to use software development kits for customers who want to integrate the ATS9416 into their own software.

A Windows compatible software development kit, ATS-SDK is also offered. It allows programs written in C/C++, C#, MATLAB, Python and LabVIEW to fully control the ATS9416. Sample programs are provided as source code.

ATS-Linux

AlazarTech offers ATS9416 binary drivers for CentOS 7.0 x86_64 with kernel 2.6.32-279.5.2.el6.x86_64. These drivers are also 100% compatible with RHEL 7.0

Also provided is a GUI application called AlazarFront-

Panel that allows simple data acquisition and display.

Source code example programs are also provided, which demonstrate how to acquire data programmatically using a C compiler.

If customers want to use ATS9416 in any Linux distribution other than the one listed above, they must purchase a license for Linux driver source code and compile the driver on the target operating system. A Non-Disclosure Agreement must also be executed between the customer's organization and AlazarTech.

All such source code disclosures are made on an as-is basis with limited support from the factory.



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System Requirements

Personal computer with at least one free x8 or x16 PCI Express slot, 16 GB RAM, 100 MB of free hard disk space, SVGA display adaptor and monitor with at least a 1024 x 768 resolution.

Power Requirements

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

Physical

Size	Single slot, half length PCIe card (4.2 inches x 6.5 inches)
Weight	250 g

I/O Connector

Analog connector	SAMTEC QSS-025-01-L-D-RA-MTI
External Trigger connector	SMB - female
Auxiliary I/O connector	SMB - female
External CLock connector	SMA - female

Environmental

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

Acquisition System

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

Timebase System

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

Dynamic Parameters

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

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

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

Optional ECLK (External Clock) Input

Signal Level	200mVp-p to 1Vp-p
Input impedance	50Ω
Input coupling	AC
Maximum frequency	100 MHz for Fast External Clock
Minimum frequency	5 MHz for Fast External Clock
Sampling Edge	Rising

Optional 10 MHz Reference Input

Signal Level	200mVp-p to 1Vp-p
Input impedance	50Ω
Input Coupling	AC coupled
Input Frequency	10 MHz ± 0.25 MHz
Sampling Clock Freq.	100 MHz

Triggering System

Mode	Edge triggering with hysteresis
Comparator Type	Digital comparators for internal (CH 1 ~ CH 16) triggering and TTL receiver for TRIG IN (External) triggering
Number of Trigger Engines	2
Trigger Engine Combination	OR
Trigger Engine Source	Any one of CH 1 ~ CH 16, TRIG IN, Software or None, independently software selectable for each of the two Trigger Engines
Hysteresis	±5% of full scale input, typical
Trigger sensitivity	±10% of full scale input range. This implies that the trigger system may not trigger reliably if the input has an amplitude less than ±10% of full scale input range selected
Trigger level accuracy	±5%, typical, of full scale input range of the selected trigger source
Bandwidth	65 MHz
Trigger Delay	Software selectable from 0 to 9,999,999 sampling clock cycles
Trigger Timeout	Software selectable with a 10 us resolution. Maximum settable



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value is 3,600 seconds. Can also be disabled to wait indefinitely for a trigger event

TRIG IN (External Trigger) Input

Input range	±3V or 3.3V TTL (5V tolerant), software selectable
Input impedance	50Ω for ±3V range 2 KΩ for TTL input
Coupling	DC only
Bandwidth (-3dB)	DC - 65 MHz
Input protection	±5V (DC + peak AC without external attenuation)

Materials Supplied

- ATS9416 PCI Express Card
- ATS9416 Installation Disk (on USB Flash Drive)

Certification and Compliances

CE Compliance

All specifications are subject to change without notice

ORDERING INFORMATION	
ATS9416-4G	ATS9416-002
ATS9416: External Clock Upgrade	ATS9416-005
SyncBoard-9416 2x	ATS9416-007
SyncBoard-9416 4x	ATS9416-008
ATS9416: Wideband Input Upgrade	ATS9416-009
SyncBoard-9416 2X-W	ATS9416-020
SyncBoard-9416 3X-W	ATS9416-021
SyncBoard-9416 4X-W	ATS9416-022
ATS9416: QSS-BNC16 Cable 36 inches	ATS9416-030
ATS9416: QSS-QSS Cable 36 inches	ATS9416-031
ATS9416: Breakout Board + Cable	ATS9416-032
Software Development Kit	ATS-SDK
Linux Driver Source for ATS9416	ATS9416-LIN

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