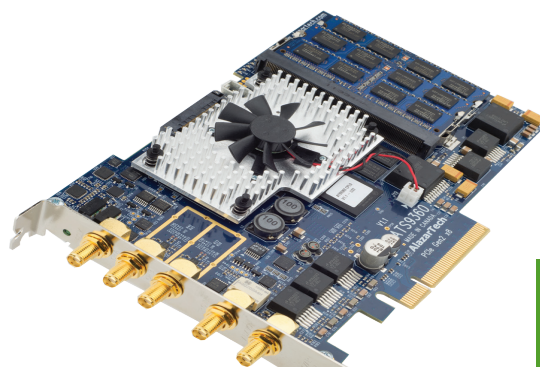# ATS9360
## 1.8GS/s 12-Bit PCIe Gen2 Digitizer

- 3.5 GB/s PCIe Gen2 (8-lane) interface
- 2 channels sampled at 12-bit resolution
- 1.8 GS/s real-time sampling rate
- FPGA based FFT processing
- Variable frequency external clocking
- Continuous streaming mode
- ±400mV fixed input range
- Asynchronous DMA device driver
- AlazarDSO oscilloscope software
- Software Development Kit supports C/C++, C#, MATLAB and LabVIEW
- Linux driver available

**RoHS compliant** 2002/95/EC

| Product | Bus | Operating System | Channels | Sampling Rate | Bandwidth | Memory Per Channel | Resolution |
|---------|-----|------------------|----------|---------------|-----------|--------------------|-----------| 
| ATS9360 | PCIe x8 Gen 2 | Win 7/8/10, Linux 2.6+ 32bit/64 bit | 2 | 1.8 GS/s to 300 MS/s | 800 MHz | 2/4 GSamples in dual/single channel mode | 12 bits |

## Overview

ATS9360 is an 8-lane PCI Express Gen 2 (PCIe x8), dual-channel, high speed, 12 bit, 1.8 GS/s waveform digitizer card capable of streaming acquired data to PC memory at rates up to 3.5 GB/s.

It is also possible to do FPGA-based 2048 point FFT on acquired data. This is useful for Optical Coherence Tomography (OCT) related applications.

Unlike other products on the market, ATS9360 does not use interleaved sampling. Each input has its own 12-bit, 1.8 GSPS ADC chip.

Optional variable frequency external clock allows operation from 1.8 GHz down to 300 MHz (or 75 MHz for screened ATS9360 cards), making ATS9360 an ideal waveform digitizer for OCT applications.

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.

ATS9360 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 ATS9360 in their own program can purchase a software development kit, ATS-SDK for C/C++ and MATLAB, or ATS-VI for LabVIEW for Windows or a Linux based ATS-Linux for C/C++ and LabVIEW for Linux.

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

## Applications

**Optical Coherence Tomography (OCT)**
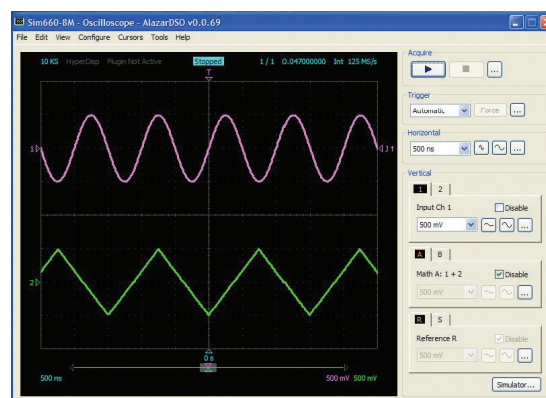
**Ultrasonic & Eddy Current NDT/NDE**

**RF Signal Recording & Analysis**

**Terabyte Storage Oscilloscope**

**High Resolution Oscilloscope**

**Spectroscopy**

**Multi-Channel Transient Recording**

## PCI Express Bus Interface

ATS9360 interfaces to the host computer using an 8-lane PCI Express bus. Each lane operates at 5.0 Gbps (Gen 2).

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, ATS9360 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 benchmark was done on ASUS P9X79 Pro and X99 Deluxe motherboards.

Workstation class computers such as Dell T7600 and HP Z430 also support 3.5 GB/s throughput.

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.

## Analog Input

An ATS9360 features two analog input channels. Each channel has up to 800 MHz of full power analog input bandwidth.

This bandwidth can optionally be extended to 1 GHz, but this upgrade must be done at the factory.

Input voltage range is fixed at ±400mV.

It must be noted that input impedance of both channels is fixed at 50Ω. Input coupling is fixed to DC.

## Acquisition System

ATS9360 PCI Express digitizers use state of the art 1.8 GSPS, 12-bit ADCs to digitize the input signals. The real-time sampling rate ranges from 1.8 GS/s down to 1 KS/s for internal clock and 300 MS/s for external clock.

The two channels are guaranteed to be simultaneous, as the two ADCs use a common 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 ATS9360.

In between the multiple triggers being captured, the acquisition system is re-armed by the hardware within 256 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 NMR spectroscopy.

## On-Board Acquisition Memory

ATS9360 has 8 GB of on-board memory, which is used as a very deep FIFO between the A/D converters and PCI Express bus. This memory is necessary to accommodate any temporary pauses in data transfer caused by the motherboard or the operating system.

## Maximum Sustained Transfer Rate

PCI Express support on different motherboards is not always the same, resulting in significantly different sustained data transfer rates. The reasons behind these differences are complex and varied and will not be discussed here.

ATS9360 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.

## Recommended Motherboards

Many different types of motherboards have been benchmarked by AlazarTech. The ones that have produced the best throughput results (3.5 GB/s) have been ASUS X99 Deluxe, ASUS P9X79 Pro and ASRock Extreme 11.

It should be noted that some motherboard and CPU combinations may behave unexpectedly. A customer purchased a multi-CPU, server class machine with *SandyBridge* CPUs, only to find out that the transfer rate was only about 400 MB/s. After a great deal of testing, the problem was identified as a bug in *SandyBridge* CPUs. Customer upgraded to the more modern *IvyBridge* CPUs and was able to achieve the full 3.5 GB/s throughput.

## No Pre-Trigger (NPT) AutoDMA

Many ultrasonic scanning and medical imaging applications do not need any pre-trigger data: only post-trigger data is sufficient.
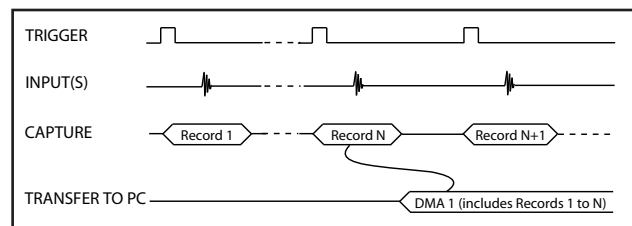
NPT AutoDMA is designed specifically for these applications. By only storing post-trigger data, the memory bandwidth is optimized and the entire on-board memory acts like a very deep FIFO.

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

Starting with FPGA version 19.02, NPT AutoDMA buffers can include a Footer that contains trigger time-stamp and other information about that particular record.

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

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.

It should be noted that even though this mode is called "No Pre Trigger", it is now possible to do limited pre-trigger data captures of up to 8192 points in single channel mode and 4096 points in dual channel mode.

## Continuous AutoDMA
Continuous AutoDMA is also known as the data streaming mode.

In this mode, data starts streaming across the PCI bus as soon as the ATS9360 is armed for acquisition. It is important to note that triggering is disabled in this mode.



TL = Transfer Length Per DMA
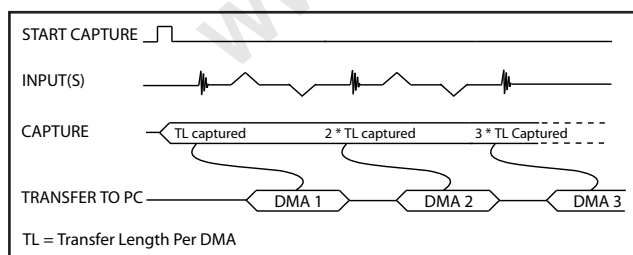
Continuous AutoDMA buffers do not include headers, so it is not possible to get trigger time-stamps.

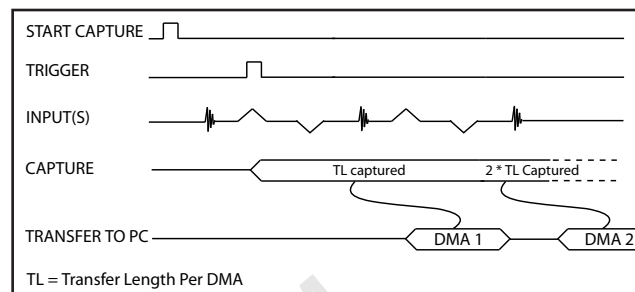A BUFFER_OVERFLOW flag is asserted only if the entire on-board memory is used up.

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 possible rate allowed by the motherboard. 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.



TL = Transfer Length Per DMA

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 possible rate allowed by the motherboard. 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.

## 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, ATS9360 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.

## FPGA Based FFT Processing

It is now possible to do real time FFT signal processing on data acquired on one channel using the on-board FPGA. Up to 200,000 2048-point FFTs can be calculated per second.

A user programmable windowing function and Dispersion Compensation Function can be applied to the acquired data before FFT calculation.

The complex FFT output is converted to magnitude in single precision floating point format. A logarithmic output can also be available.

## GPU Based FFT Processing or Other DSP

ATS-GPU is a software library sold separately by AlazarTech that allows users to stream acquired data to a Graphical Processing Unit (GPU) under Windows operating system (Linux is not supported at this time). Data streaming rates of up to 1.5 GB/s have been demonstrated.

Users can do FFT signal processing using any Open-CL compatible GPU, e.g. STRIX-GTX960. One advantage of using ATS-GPU over the FPGA based FFT is that FFT lengths can be very long - even millions of points.

ATS-GPU is written in OpenCL.

## Triggering

ATS9360 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, ATS9360 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

ATS9360 external trigger input (TRIG IN) can be set as an analog input with ±2.5V full scale input range and 50Ω input impedance, or a 3.3V TTL input.

When TTL input is selected, the input impedance increases to approximately 2 KΩ, making it easier to drive the TRIG IN input from high output impedance sources.

## Timebase

ATS9360 timebase can be controlled either by on-board low-jitter VCO or by optional External Clock.

On-board low-jitter VCO uses an on-board 10 MHz TCXO as a reference clock. Clock buffers used feature less than 76 $fs_{RMS}$ additive jitter.

## Optional External Clock

While the ATS9360 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.

ATS9360 External Clock option provides an SMA input for an external clock signal, which can be a sine wave or square wave signal of minimum 400mV$_{p-p}$ amplitude. External clock amplitude must not exceed 2V$_{p-p}$.

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

There are two types of External Clock supported by ATS9360. These are described below.

### Fast External Clock

A new sample is taken by the on-board ADCs for each rising edge of this 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 300 MHz and lower than 1.8 GHz.

For customers whose external clocks may go lower than 300 MHz during the acquisition, it is possible to have AlazarTech screen the ATS9360 boards for external clock operation down to 75 MHz (Order number ATS9360-006)

This is the ideal clocking scheme for OCT applications.

### 10 MHz Reference Clock

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.

ATS9360 uses an on-board low-jitter VCO to generate a user-specified high frequency clock used by the ADC. This sampling clock can be virtually any multiple of 1 MHz.

## AUX Connector

ATS9360 provides an AUX (Auxiliary) SMA connector that is configured as a Trigger Output connector by default.

When configured as a Trigger Output, AUX SMA connector outputs a 5 Volt TTL signal synchronous to the

ATS9360 Trigger signal, allowing users to synchronize their test systems to the ATS9360 Trigger.

When combined with the Trigger Delay feature of the ATS9360, this option is ideal for ultrasonic and other pulse-echo imaging applications.

AUX connector can also be used as a Trigger Enable input for frame (B-scan) capture applications.

## Calibration
Every ATS9360 digitizer is factory calibrated to NIST-traceable standards. To recalibrate an ATS9360, the digitizer must either be shipped back to the factory or a qualified metrology lab.

## On-Board Monitoring
Adding to the reliability offered by ATS9360 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
ATS9360 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.

AlazarDSO also includes a Stream-to-Memory tool at no charge. This allows the customer to allocate as much system memory as Windows can allow, and use that memory to stream data. Once the data is captured in memory, software saves it to a file on a regular disk drive. This capability is very useful for customers who want to acquire a large dataset for algorithm development or proof of concept without having to write any code.

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

## Software Development Kits
AlazarTech provides an easy to use software development kit for customers who want to integrate the ATS9360 into their own software for Windows or Linux operating systems.

This software development kit, called ATS-SDK, includes headers, libraries and source code sample programs written in C/C++, C#, MATLAB, LabVIEW and Python. These programs can fully control the ATS9360 and acquire data in user buffers.

## ATS-GPU
ATS-GPU is a software framework developed by AlazarTech to allow users to do real-time data transfer from ATS9360 to an Open CL compatible Graphical Processing Unit (GPU) at rates up to 1.5 GB/s.

Modern GPUs include very powerful processing units and a very high speed graphical memory bus. This combination makes them perfectly suited for parallel signal processing applications.

The floating point FFT routines built into ATS-GPU have been optimized to provide the maximum number of FFTs per second. Kernel code running on the GPU can do zero-padding, apply a windowing function, do a floating point FFT, calculate the amplitude and convert the result to a log scale.

FFTs can be done on triggered data or on continuous gapless stream of data. It is also possible to do spectral averaging. Our benchmarks showed that it was possible to do 630,000 FFTs per second when capturing data in single-channel mode and using an NVIDIA GeForce GTX 560 Ti GPU.

ATS-GPU also includes source code of the software framework required to transfer data from a waveform digitizer to a GPU and from the GPU to user application. Users can use this framework to create their own GPU-based analysis function.

## Support for Linux
AlazarTech offers ATS9360 binary drivers for CentOS 6.3 x86_64 with kernel 2.6.32-279.5.2.el6.x86_64. These drivers are also 100% compatible with RHEL 6.3.

Also provided is a GUI application called AlazarFrontPanel that allows simple data acquisition and display.

The source code example programs included with ATS-SDK work seemlessly with the Linux drivers as well. These programs demonstrate how to acquire data programmatically using a C compiler.

There are two options for customers who want to use ATS9360 in a Linux distribution other than the one listed above:

1) Provide AlazarTech with the full output of the uname -a command from the target computer. If it is feasible, AlazarTech will create a binary driver for the customer's chosen distribution.

2) 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.

# ATS9360
## 1.8GS/s 12-Bit PCIe Gen2 Digitizer

**AlazarTech**

## System Requirements

Personal computer with at least one free x8 or x16 PCI Express slot (must be Gen 2 or Gen 3 slot to achieve full data throughput), 4 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 | 1.2 A, typical |
| +3.3V | 3.0 A, typical |

## Physical

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

## I/O Connectors

| | |
|---|---|
| ECLK, CH A, CH B, TRIG IN, AUX I/O | SMA female connector |

## 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 | 12 bits |
| Bandwidth (-3dB) DC-coupled, 50Ω | DC - 800 MHz, typical |
| Number of channels | 2, simultaneously sampled |
| Maximum Sample Rate | 1.8 GS/s single shot |
| Minimum Sample Rate | 1 KS/s single shot for internal clocking |
| Full Scale Input ranges 50 Ω input impedance: | ±400mV |
| DC accuracy | ±2% of full scale in all ranges |
| Input coupling | DC |
| Input impedance | 50Ω ±1% |
| Input protection 50Ω | ±4V (DC + peak AC for CH A, CH B and EXT only without external attenuation) |

## Timebase System

| | |
|---|---|
| Timebase options | Internal Clock or External Clock (Optional) |
| Internal Sample Rates | 1.8GS/s, 1.5GS/s, 1.2GS/s, 1GS/s, 800 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 |
| Internal Clock accuracy | ±2 ppm |

## Dynamic Parameters

Typical values measured on the 200 mV range of CH A of a randomly selected ATS9360. 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 9.9 MHz and output amplitude was 135 mV rms, which was approximately 95% of the full scale input. Input was averaged.

| | |
|---|---|
| SNR | 57.1 dB |
| SINAD | 56.6 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 | 400mV$_{p-p}$ to 1.6 V$_{p-p}$ sine or square wave |
| Input impedance | 50Ω |
| Input coupling | AC |
| Maximum frequency | 1.8 GHz for Fast External Clock |
| Minimum frequency | 300 MHz for Fast External Clock |
| Minimum frequency for boards screened for Min.External Clock | 75 MHz for Fast External Clock |
| Sampling Edge | Rising only |

## Optional 10 MHz Reference Input

| | |
|---|---|
| Signal Level | ±200mV Sine wave or square wave |
| Input impedance | 50Ω |
| Input Coupling | AC coupled |
| Input Frequency | 10 MHz ± 0.25 MHz |
| Sampling Clock Freq. | Any multiple of 1 MHz between 300 MHz and 1.8 GHz |

## Triggering System

| | |
|---|---|
| Mode | Edge triggering with hysteresis |
| Comparator Type | Digital comparators for internal (CH A, CHB) triggering and analog comparators for TRIG IN (External) triggering |
| Number of Trigger Engines | 2 |
| Trigger Engine Combination | OR |
| 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 | ±5%, typical, of full scale input range of the selected trigger source |
| Bandwidth | 250 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 |
|---|---|

## TRIG IN (External Trigger) Input

| Input range | ±2.5 V or TTL Input, software selectable |
|---|---|
| Input impedance | 50 Ω for ±2.5 V range<br>2 KΩ for TTL input |
| Coupling | DC only |
| Bandwidth (-3dB) | DC - 250 MHz |
| DC accuracy | ±10% of full scale input |
| Input protection | ±8V (DC + peak AC without external attenuation) |

## TRIG OUT Output

| Connector Used | AUX I/O |
|---|---|
| Output Signal | 5 Volt TTL |
| Synchronization | Synchronized to a clock derived from the ADC sampling clock. Divide-by-4 clock (dual channel mode) or divide-by-8 clock (single channel mode) |

## Materials Supplied

ATS9360 PCI Express Card

ATS9360 Install Disk on USB flash drive

## Certification and Compliances

CE Compliance

*All specifications are subject to change without notice*

## ORDERING INFORMATION

| | |
|---|---|
| ATS9360-4G | ATS9360-101 |
| ATS9360: External Clock Upgrade | ATS9360-005 |
| ATS9360: Screened Ext Clk Upgrade | ATS9360-006 |
| SyncBoard-9360 2X-W | ATS9360-007 |
| SyncBoard-9360 4X-W | ATS9360-008 |
| Software Development Kit<br>(Supports C/C++, LabVIEW, MATLAB and Python) | ATS-SDK |
| Linux Driver Source Code for ATS9360 | ATS9360-LIN |
| GPU interface library for Windows | ATSGPU-WIN |