Brilliant Instruments

BI200

Time Interval Analyzer

FEATURES

- Direct Time Measurement of Pulse Trains
- Measure Jitter, Frequency, Time Interval (Skew), Pulse Width, Risetime, Event Timing, Time Interval Error (TIE), and More
- 3ps Single-Shot Resolution (12 Digits/s Frequency)
- DC to 2GHz / 4Gb/s Frequency Range. All functions Including Pulsewidth Work Over the Entire Frequency Range
- Up to 4 Million Continuous Zero Dead Time Measurements Per Second
- 200ps Minimum Pulse Width
- Highly Sophisticated and Flexible Arming (Triggering)
- PCI Express Interface for Super High Throughput
- On-board Memory for 4 Million Measurement Points – Can Be Read While Measurements are Taking Place

More Tests in Less Time

The BI200 is an ultra high performance time and frequency measurement instrument. Its high resolution and throughput, combined with continuous measurement capability, allow you to make measurements that are not possible with traditional time-interval counters. For example, it can timetag events (edges of an input pulse train) at a rate of 4 million per second continuously to on-board memory, while each of the edges is measured with 3ps resolution. This provides it with the capability to analyze the dynamic variations in pulse timing, pulsewidth, or frequency. In other words, the difference between the BI200 and a traditional counter/timer is analogous to the difference between a voltmeter and a scope. Measurements can also be streamed continuously over the PCI Express interface allowing unlimited acquisition at high rates.

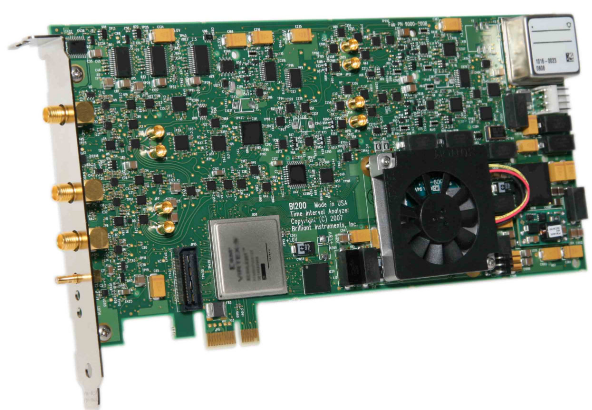
Full-Featured Instrument

The BI200 is a full instrument-on-a-card with all the features and capabilities you would expect in a bench-top instrument including high quality inputs, built-in NIST traceable calibration, and software and hardware that deliver fully computed results. The instrument has 10 measurement functions such as Frequency, Time Interval and Pulsewidth. All functions work directly on the input signal at frequencies up to 2GHz (4Gb/s) without any prescaling. This means that you can measure pulses as narrow as 200ps, occurring at frequencies up to 2GHz, or the skew between two signals at 4Gb/s.

The inputs of the instrument include programmable termination voltage and hysteresis. These are features that are seldom found even in the best of the bench-top instruments. When you connect your signal source to the BI200 it sees a 50 ohm load which is terminated to an accurately programmable voltage between -2V and +3V. This allows you to connect ECL, PECL, or CML sources directly to the instrument with the proper loading. It even allows you to terminate the signal from CMOS sources to a center voltage which provides a symmetrical load for superior performance. The programmable hysteresis is an important feature for signals with slow risetime or high noise levels. It sets different threshold levels for the rising edge and the falling edge which prevents false triggering.

APPLICATIONS

- PLLs and frequency modulation – measure jitter, time interval error and settling time
- Ultrasonic and radar pulse timing
- Optical and magnetic disk drive – measure jitter, risetime, and bit timing directly
- PCI Express and other high speed serial interfaces – measure jitter and skew
- Oscillators and crystals – measure frequency, start-up time and time interval error
- Pulse width modulated signals – measure variations over time
- Nuclear physics
- Time stamping of events in real time



Easy to Use Software

The software for the BI200 is designed for ease of use and extremely high performance. The driver software automatically manages the streaming of measurements at the super high rates which are possible with the PCI Express interface. The front panel software for Windows® allows you to easily set up multiple simultaneous displays of the measurements. This gives multiple views of the same data, or different functions from the same data. For example, you can set up the display to show a graph of the frequency of the signal vs. time, plus a tabular display of the same results, plus a graph of the time deviation of the signal vs. time, all from the same measurement acquisition run. The front panel can also run multiple instruments simultaneously.

The actual screen shot in the following page shows three views of the same Time Interval Error (TIE) measurement of a clock signal. Notice how the graph clearly shows a repetitive deviation in the clock edge timing of about 8ps which occurs about every 170ms. Also, note the rms jitter of 3.8ps which is shown in the digital display. This is the jitter of the signal plus the instrument measurement noise. The table display provides additional information about each of the measurement points.

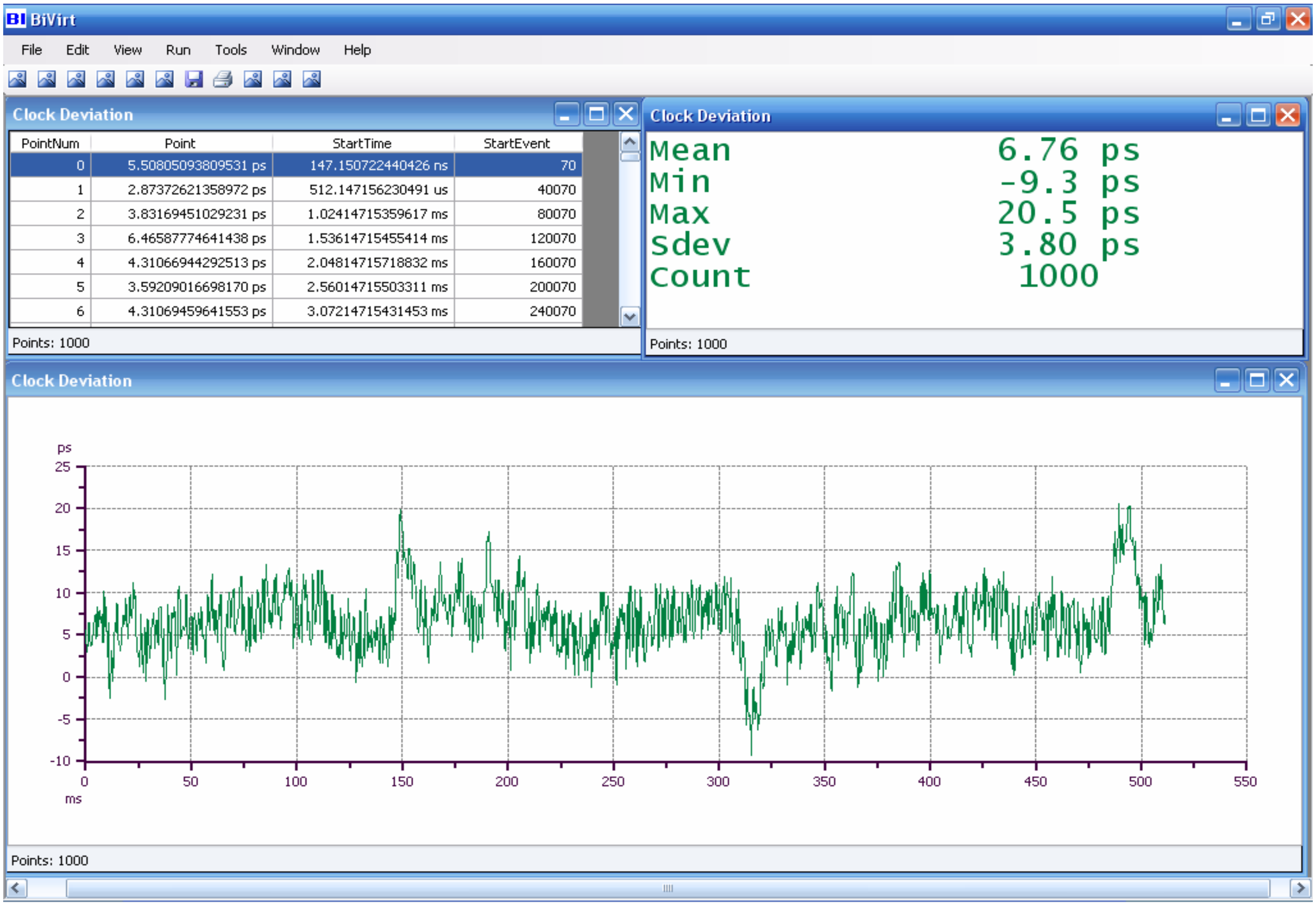


Figure 1: Screen shot of the measurement of an actual clock signal with crosstalk disturbance

HOW DOES IT WORK?

The simplified block diagram on the right shows the key components of the instrument from the user's point of view. The input signal is terminated by 50 ohms to a user-programmable voltage (Vt) and fed to a comparator. The comparator output goes high when the signal crosses a user-programmable threshold voltage (Vth). At this point the signal is a digital waveform whose rising or falling edges are considered to be "events". These events are continuously counted by the Event Counter, while the Arming System selects the edges which are to be timetagged according to the user configuration. For example, you can set up the instrument to timetag every N events, or every T seconds.

When an event is timetagged, the event count (pulse number) and the time of the occurrence are logged to memory. The Timetag Circuits require a recovery time of 250ns to be ready for another timetag. Note, however, that the signal is still counted by the Event Counter, so no information is lost. This recovery time means that up to 4 million timetags (or pairs of timetags) can be logged per second. From this timetag data, the instrument calculates the measurement results.

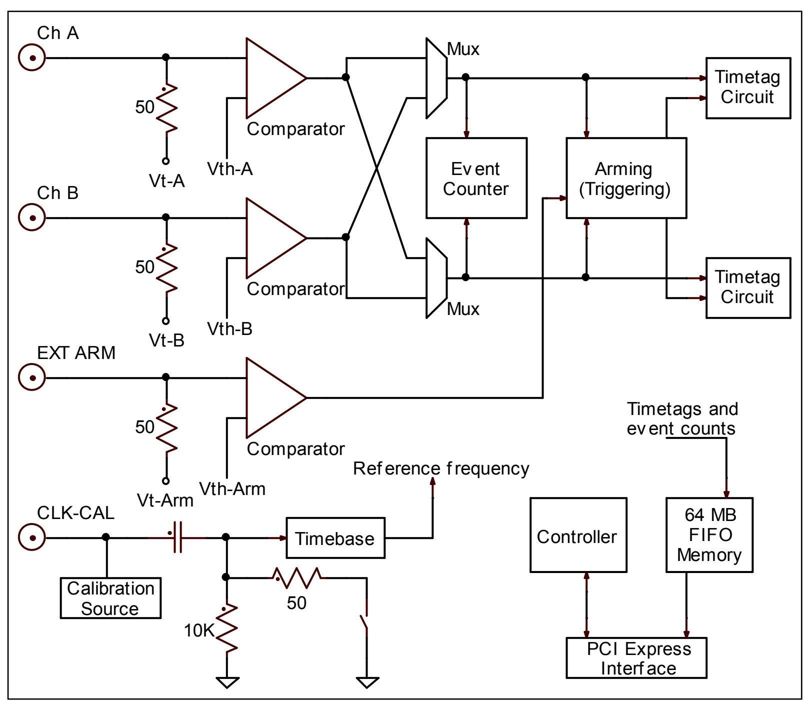


Figure 2: Simplified block diagram

There are three groups of measurement functions – 1C1E, 1C2E, and 2C2E. The timing diagrams below illustrate the operation of the instrument for each group.

One-Channel-One-Edge Functions

The 1C1E functions (one-channel-one-edge) operate on a single channel (either A or B) and use only one timetagging circuit. That is, each timetag contains only one edge time and one event count. The recovery time of 250ns is the minimum time between timetags. That is, for frequencies below 4MHz it is possible to measure every rising or falling edge. The equations for the first measurement point in the timing diagram are shown in the table below. For example, in the equation for Frequency Average E1 and E2 are event counts while T1 and T2 are the time information from the first two timetags. Note that you can make up to 4 million frequency measurements per second on a continuous zero-dead-time basis. The measurement points are back to back since the end of one point is the start of the next one.

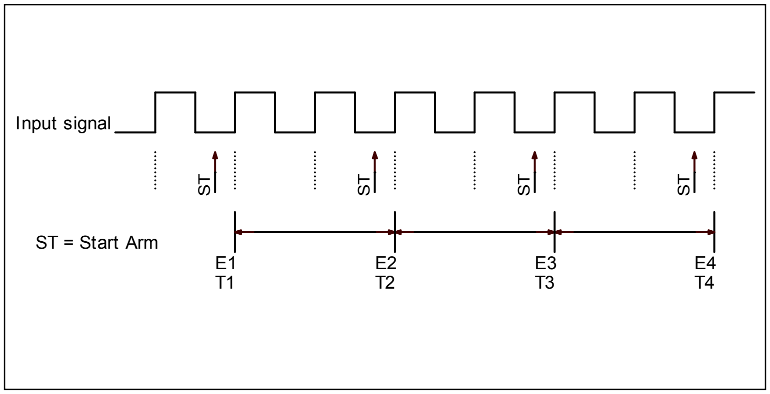


Figure 3: 1C1E functions

Function	Calculation	Notes
Frequency Average	$FreqAvg = \frac{\Delta E}{\Delta T} = \frac{E2 - E1}{T2 - T1}$	Average frequency of the input signal
Period Average	$PeriodAvg = \frac{\Delta T}{\Delta E} = \frac{T2 - T1}{E2 - E1}$	Average period of the input signal
Continuous Time Interval	$CTI = \Delta T = T2 - T1$	The actual time between pairs of timetags
Time Interval Error	$TIE = T1 - ExpectedTime$	The deviation in time of each of the timetags from an expected value. The user supplies the reference period of the signal

One-Channel-Two-Edge Functions

The 1C2E functions (one-channel-two-edge) operate on a single channel (either A or B) and use both timetagging circuits. That is, each timetag contains two edge times and one event count. The recovery time of 250ns is the minimum time between the stop timetag and the next start timetag. For all these functions the result is the difference in time from the start to the stop. The associated event count is for the start event. The arming that the user specifies is for the Start Arm, while the Stop Arm is dictated by the function.

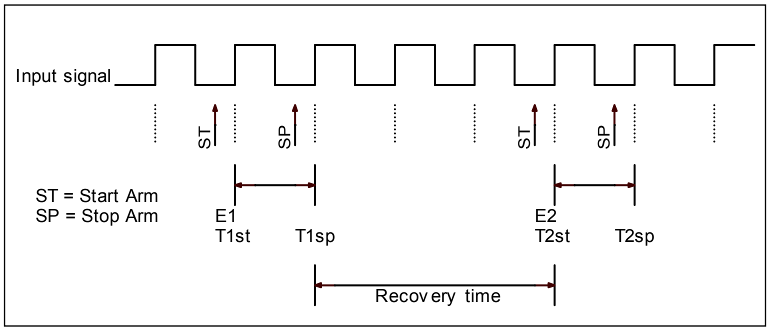


Figure 4: 1C2E functions

Function	Stop Arm	Notes
Period	Next same edge	Measures single periods of the input signal
Pulsewidth	Next opposite edge	Measures individual pulsewidths of the input signal
One-Channel Time Interval	Next signal edge	The polarity of the start and stop edges is specified by the user
Risetime, Falltime	Same signal edge	Measures a single edge with two thresholds, usually 20% and 80%

Two-Channel-Two-Edge Functions

The 2C2E functions (two-channel-two-edge) operate on both channels (A to B or B to A) and use both timetagging circuits. That is, each timetag contains two edge times and one event count. The recovery time of 250ns is the minimum time between the stop timetag and the next start timetag. For the 2-Ch Time Interval function the result is the difference in time from the start to the stop. The associated event count is for the start event. The user can specify the polarity of the start edge and the stop edge and a delay for the Stop Arm. The delay provides for the exact selection of the stop edge. For example, when the Stop Arm Delay is set to 0, the instrument will measure down to a 0 time interval (zero skew between channel A and B).

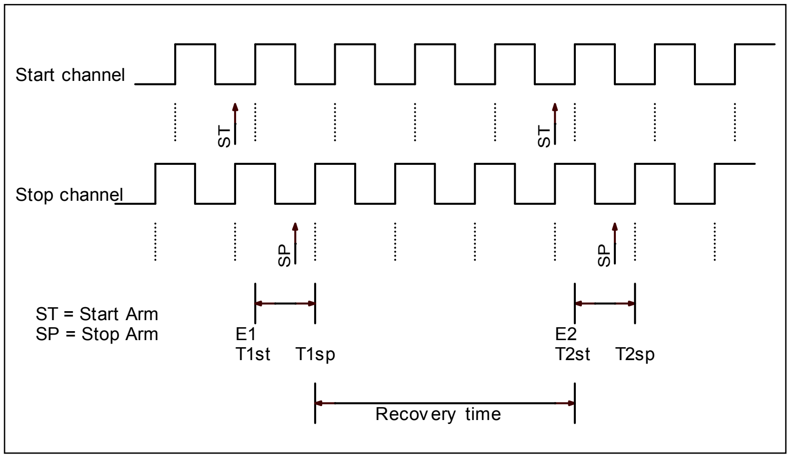


Figure 5: 2C2E functions

SPECIFICATIONS

General

- See "Definitions" below for explanation of the terms in the specifications
- Warranty: 1 year

Measurement Functions

- Fully symmetrical operation – all functions are the same for channel A or B
- One-Channel One-Edge (1C1E) Functions:
  - Frequency Average
  - Period Average
  - Continuous Time Interval (CTI)
  - Time Interval Error (TIE)
- One-Channel Two-Edge (1C2E) Functions:
  - Period (Per)
  - Pulsewidth (PW)
  - 1-Ch Time Interval (TI1)
  - Risetime
  - Falltime
- Two-Channel Two-Edge (2C2E) Functions:
  - 2-Ch Time Interval (TI2)

Frequency Average A or B

- Measures the average frequency between pairs of events on a zero-dead-time basis (measurements are back to back)
- Type: 1C1E (One-Channel One-Edge)
- Frequency range: 0.15Hz to 2GHz (4Gb/s)
- Measurement time ("gate time"): 250ns to 6.8s
- Number of events for each measurement point: 1 to 4.29 billion (limits measurement time to 2.14s at 2GHz)
- Number of significant digits: 12 digits/s (9 digits in 1ms, or 6 digits in 1µs) regardless of input frequency
- Resolution (in Hz rms):

$$\pm\frac{Freq\times(3\,ps(rms)+1.4\times TriggerError)}{Meastime}$$

- Accuracy (in Hz): ±Resolution ± TimebaseErr

Period Average A or B

- Measures the average period between pairs of events on a zero-dead-time basis (measurements are back to back)
- Type: 1C1E (One-Channel One-Edge)
- Range: 500ps to 6.8s
- See Frequency Average function for measurement time, number of events, and significant digits
- Resolution (in seconds rms):

$$\pm\frac{Period\times(3\,ps(rms)+1.4\times TriggerError)}{Meastime}$$

- Accuracy (in seconds): ±Resolution ± TimebaseErr

Continuous Time Interval (CTI) A or B

- Measures the time between pairs of events on a zero-dead-time basis (measurements are back to back)
- Type: 1C1E (One-Channel One-Edge)
- Range: 250ns to 6.8s
- Measurement time: 250ns to 6.8s (can comprise multiple periods of the input signal)
- Number of events during measurement: 1 to 4.29 billion (limits measurement time to 2.14s at 2GHz)
- Resolution:

  ± 3ps(rms) ± 1.4 x TriggerErr
- Accuracy: ±Resolution ± TimebaseErr ± 10ps

Time Interval Error (TIE) A or B

- Measures the time of occurrence of events, then calculates the deviation from the expected period of the signal
- Type: 1C1E (One-Channel One-Edge)
- Frequency range: 0.15Hz to 2GHz (4Gb/s)
- Measurement repetition rate: 250ns to 6.8s
- Number of events between points: 1 to 4.29 billion (limits measurement repetition to 2.14s at 2GHz)
- Resolution:

  ± 3ps(rms) ± 1.4 x TriggerErr
- Accuracy: ±Resolution ± TimebaseErr ± 10ps

Period A or B

- Measures single periods of the signal
- Type: 1C2E (One-Channel Two-Edge)
- Range: 500ps to 6.8s
- Frequency range: 0.15Hz to 2GHz (4Gb/s)
- Time between measurements: 250ns to 6.8s
- Resolution: ± 3ps(rms) ± 1.4 x TriggerErr
- Accuracy: ±Resolution ± TimebaseErr ± 30ps

Pulsewidth A or B

- Measures pulse widths of the signal
- Type: 1C2E (One-Channel Two-Edge)
- Range: 200ps to 6.8s
- Frequency range: 0.15Hz to 2GHz (4Gb/s)
- Time between measurements: 250ns to 6.8s
- Resolution: ± 3ps(rms) ± 1.4 x TriggerErr
- Accuracy:

  ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 30ps

1-Ch Time Interval A or B

- Measures time intervals between edges of the input signal, with selectable polarity
- Type: 1C2E (One-Channel Two-Edge)
- Range: 200ps to 6.8s
- Frequency range: 0.15Hz to 2GHz (4Gb/s)
- Time between measurements: 250ns to 6.8s
- Resolution: ± 3ps(rms) ± 1.4 x TriggerErr
- Accuracy:

  ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 30ps

Risetime A or B, Falltime A or B

- Measures risetime or falltime of the input signal
- Type: 1C2E (One-Channel Two-Edge)
- Two thresholds (trigger) levels are set
- Range: 0ps to 6.8s
- Frequency range: DC to 2GHz (4Gb/s)
- Time between measurements: 250ns to 6.8s
- Resolution: ± 3ps(rms) ± 1.4 x TriggerErr
- Accuracy:

  ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 20ps

2-Ch Time Interval (TI2) A-to-B or B-to-A

- Measures the time between edges of signals from two channels
- Type: 2C2E (Two-Channel Two-Edge)
- Range: -50ps to 6.8s
- Frequency range: 0.15Hz to 2GHz (4Gb/s)
- Time between measurements: 250ns to 6.8s
- Resolution:

  ± 3ps(rms) ± StartTriggerErr ± StopTriggerErr
- Accuracy:

  ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 30ps

Inputs and Outputs

Ch A and B

- Frequency range: DC to 2GHz (4Gb/s)
- Minimum pulse width: 200ps
- Connector: SMA
- Coupling: DC
- Input impedance: 50Ω into a user programmable termination voltage
- Termination voltage (Vt): -2.0V to +3.0V (see restrictions below)
  - Resolution: 100µV
  - Accuracy: 3mV
- Trigger Threshold voltage (Vth): -3.0V to +5.0V (see restrictions below)
  - Resolution: 200µV
  - Accuracy: 6mV
- Slope: Positive or negative
- Sensitivity: 50mV rms sine, 50mVp-p pulse
- Hysteresis – prevents false triggering by having separate threshold levels for rising and falling edges
  - Range: 1mV to 50mV
- Minimum slew rate of input signal
  - Hysteresis > (20mV or noise level): no minimum
  - Hysteresis = 1mV: 200V/µs (for 1Vp-p sinewave, minimum frequency is 62MHz)
- Restrictions on input signal (Vi), trigger threshold voltage (Vth), and termination voltage (Vt). All of these restrictions must be met. For example, if Vt is 1.5V and Vth is 0.5V, the third equation states that the input signal can range from -4.5V to + 3.5V. However, the sixth equation restricts the lower end further to -2.0V for DC signals and the seventh equation restricts it to -3.5V for AC signals. For convenience, the instrument software reports the allowed ranges.
  - $-2 \le Vt \le +3$
  - $-2 \le Vt - Vth \le +2$
  - $-4 \le Vi + Vt - 2Vth \le +4$
  - $-4 \le Vth + Vt \le +6$
  - $-4 \le Vi + Vt \le +6$
  - $-3.5 \le Vi - Vt \le +3.5$ (DC)
  - $-5 \le Vi - Vt \le +5$ (AC: 50% duty cycle, >1 kHz)
  - Some representative examples:

Application	Vt	Vth	Vi min	Vi max
General	0	0	-3.5	+3.5
CMOS (3V)	1.5	1.5	-2.0	+4.5
CMOS (5V)	2.5	2.5	-1.0	+3.5*
PECL (3.3V)	1.3	2.0	-1.3	+4.7
CML (2.5V)	2.5	2.3	-1.0	+3.5

*Attenuation is required for 5V CMOS (see User Manual)

EXTARM Input

- Connector: SMA
- Frequency range: DC to 1.5GHz
- Minimum pulse width: 300ps
- Hysteresis: 40mV typical, fixed
- Setup time: 3ns ±100ps (factory calibrated)
- All other input characteristics are the same as for Channel A and B, including threshold and termination settings

EXTCLK Input / CAL Output

- Connector: SSMB (adapter to SMA is available)
- Input for external timebase reference
  - Coupling: AC
  - Impedance: Programmable to 50Ω or 10kΩ
  - Amplitude: 200mVp-p to 4Vp-p
- Output for calibration signal (see manual for instructions)

Definitions

- TriggerErr or StartTriggerErr or StopTriggerErr
  - Error due to noise superimposed on the input signal from both internal and external sources
  - $TriggerErr = \frac{\sqrt{300\mu V^2 + E_n^{\,2}}}{InputSignalSlewRate}$ s rms
  - En = RMS noise of input signal (8GHz bandwidth)
  - InputSignalSlewRate = Slew rate of input signal (V/s) at the threshold point
- TriggerLevelTimeErr
  - Time error due to threshold uncertainty
  - $TriggerLevelTimeErr = \frac{< 6mV}{InputSignalSlewRate}$ s rms
  - Example: For input signal slew rate = 2000V/µs TriggerLevelTimeErr = 3ps
- TimeBaseErr
  - Fractional Frequency error of timebase reference, times the measurement result

Arming

Each measurement run is composed of multiple blocks with multiple "points" in each block. For example, 1000 blocks of 1000 pulsewidth points can be taken, for a total of 1 million points. Statistical results are provided for each block, and for the whole set of blocks.

Arming is the enabling of measurement points or blocks. There is separate arming for blocks and for points.

Block Arm

- Mode
  - On Channel A edge (same polarity as measured edge)
  - On Channel B edge (same polarity as measured edge)
  - On EXT ARM rising edge
  - By Time – every 512 ns to 3.43 s, 12.8 ns resolution
  - Immediate – run as quickly as possible
  - By software command
- Number of blocks: 1 to 16,777,215 or "endless"

Start Arm

Arms the start of each measurement point.

- Mode
  - By events – every set number of edges of the input signal
    - Number of events: 1 to 4,294,967,295
  - On Channel A edge (1C2E functions on Ch A only)
  - On Channel B edge (1C2E functions on Ch B only)
  - On EXT ARM rising edge
  - By Time – every 256ns to 3.43s, 12.8 ns resolution
  - Immediate – run as quickly as possible
  - By software command
- Number of points per block: 1 to 16,777,215 or "endless" (2 to 16,777,215 for 1C1E functions)

Stop Arm

- 1C1E functions: Not used
- 1C2E functions: Automatically configured for the specific function
- 2C2E functions: Stop Arm occurs after the start edge of the signal plus a user programmable delay
  - Delay range: -50ps to 500ps
  - Negative setting allows the measurement of time intervals down to 0 (simultaneous edges on both channels)

Timebase

- Internal NIST traceable 10MHz oven oscillator
  - Over full temperature range: ±0.02 ppm
  - Aging: ±0.001 ppm/day, ±0.3 ppm/year
  - Warm-up time: 5 minutes
- External 10MHz reference input
  - Frequency: 10MHz ±50ppm (±500Hz)
  - See "Inputs and Outputs" section above for signal characteristics

Memory

- 64MB on-board
  - Up to 5.5 million points in 1C1E functions
  - Up to 4 million points in 1C2E and 2C2E functions
- Memory can be read out while measurements are accumulating, allowing unlimited continuous measurements

Math and Statistics

- Performs additional mathematical operations on the measurement results
  - Scaling and normalizing
  - Calculating relative error
- Calculates statistics on blocks of measurements and on the total set of blocks
  - Mean, Min, Max, and Standard Deviation

Software

- Windows® driver
  - Provides an extremely powerful set of functions for controlling the instrument and for data analysis
  - Includes tools for high speed reading of the instrument which take advantage of the PCI Express interface without burdening the user with the details
  - Compatible with Windows® 95 and later
  - Written in plain C++, can be ported to Linux
- Virtual Front Panel (Windows® based)
  - Provides multiple simultaneous displays for the same measurement. The displays can even be different functions, as long as they are from the same group (1C1E, 1C2E, or 2C2E)
    - Graphs of results vs. time
    - Histogram
    - Numerical results (digital display)
    - Table of results and internal data
    - Streaming of results to a file
  - Can run multiple instruments simultaneously
  - Compatible with Windows® XP/Vista 32-bit
  - Requires .NET Framework 3.5 (available free from Microsoft™)

Computer Requirements

- One x1 or higher PCI Express slot
- Size: 4.4”x8.6” (11.2x21.9cm) excluding bracket
- Does not support hot plug-in for PCIe
- 256MB RAM, 10MB disk space
- 800x600 minimum display resolution

Calibration

- Traceable calibration once a year
  - Requires a voltmeter and a frequency reference
- Internal calibration automatically calibrates the instrument against the internal voltage and frequency references

Power, Cooling and Physical

- Power supply requirements (typical):

From PCIe bus:	3.3V @ 2.2A	12V @ 0.2A
From auxiliary power:	5V @ 0.9A	12V @ 1.3A

- Total power consumption: 30W typical
- Auxiliary power connector type: AMP 4-pin header part number 171826-4 (typically used for floppy disks). Mating connector type is AMP part number 171822-4
- Operating temperature range: 0°C to 45°C
- On-board fan automatically turns on based on temperature sensors
- Good ventilation of slots in PC is recommended to prevent on-board fan from turning on
- Weight: 9.9 Oz (280 g)

*Specifications are subject to change without notice

5/1/09