

FEATURES

- Direct Time Measurement of Pulse Trains
- Measure Jitter, Frequency, Time Interval (Skew), Pulse Width, Risetime, Event Timing, Time Interval Error (TIE), and More
- 3 ps Single-Shot Resolution (12 Digits/s Frequency)
- DC to 2 GHz / 4 Gb/s (BI200), 800 MHz / 1.6 Gb/s (BI201) Frequency Range. All Functions Including Pulsethrough Work Over the Entire Frequency Range
- Up to 4 Million Continuous Zero Dead Time Measurements Per Second
- 100 ps Minimum Pulse Width
- Highly Sophisticated and Flexible Arming (Triggering)
- PCI Express Interface for Super High Throughput
- On-board Memory for 8 Million Measurement Points – Can Be Read While Measurements are Taking Place

More Tests in Less Time

The BI200/BI201 are ultra high performance time and frequency measurement instruments. Their 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, they can time-tag 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 3 ps resolution. This provides them with the capability to analyze the dynamic variations in pulse timing, pulsethrough, or frequency. In other words, the difference between the BI200/BI201 and traditional counter/timers is analogous to the difference between voltmeters and scopes. Measurements can also be streamed continuously over the PCI Express bus allowing unlimited acquisition at high rates.

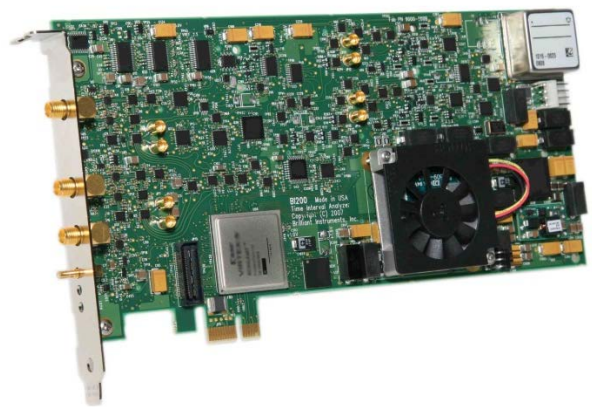
Full-Featured Instruments

The BI200/BI201 are full instruments-on-a-card with all the features and capabilities you would expect in bench-top instruments including high quality inputs, built-in NIST traceable calibration, and software and hardware that deliver fully computed results. The instruments have 10 measurement functions such as Frequency, Time Interval and Pulsethrough. All functions work directly on the input signal at frequencies up to 2 GHz (4 Gb/s) for the BI200, or 800 MHz (1.6 Gb/s) for the BI201 without any prescaling. This means that with the BI200 you can measure pulses as narrow as 100 ps, occurring at frequencies up to 2 GHz, or the skew between two signals at 4 Gb/s.

The inputs of the instruments 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/BI201 it sees a 50 ohm load which is terminated to an accurately programmable voltage between -2 V and +3 V. This allows you to connect ECL, PECL, or CML sources directly to the instruments 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.

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/BI201 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 8 ps which occurs about every 170 ms. Also, note the rms jitter of 3.8 ps 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.

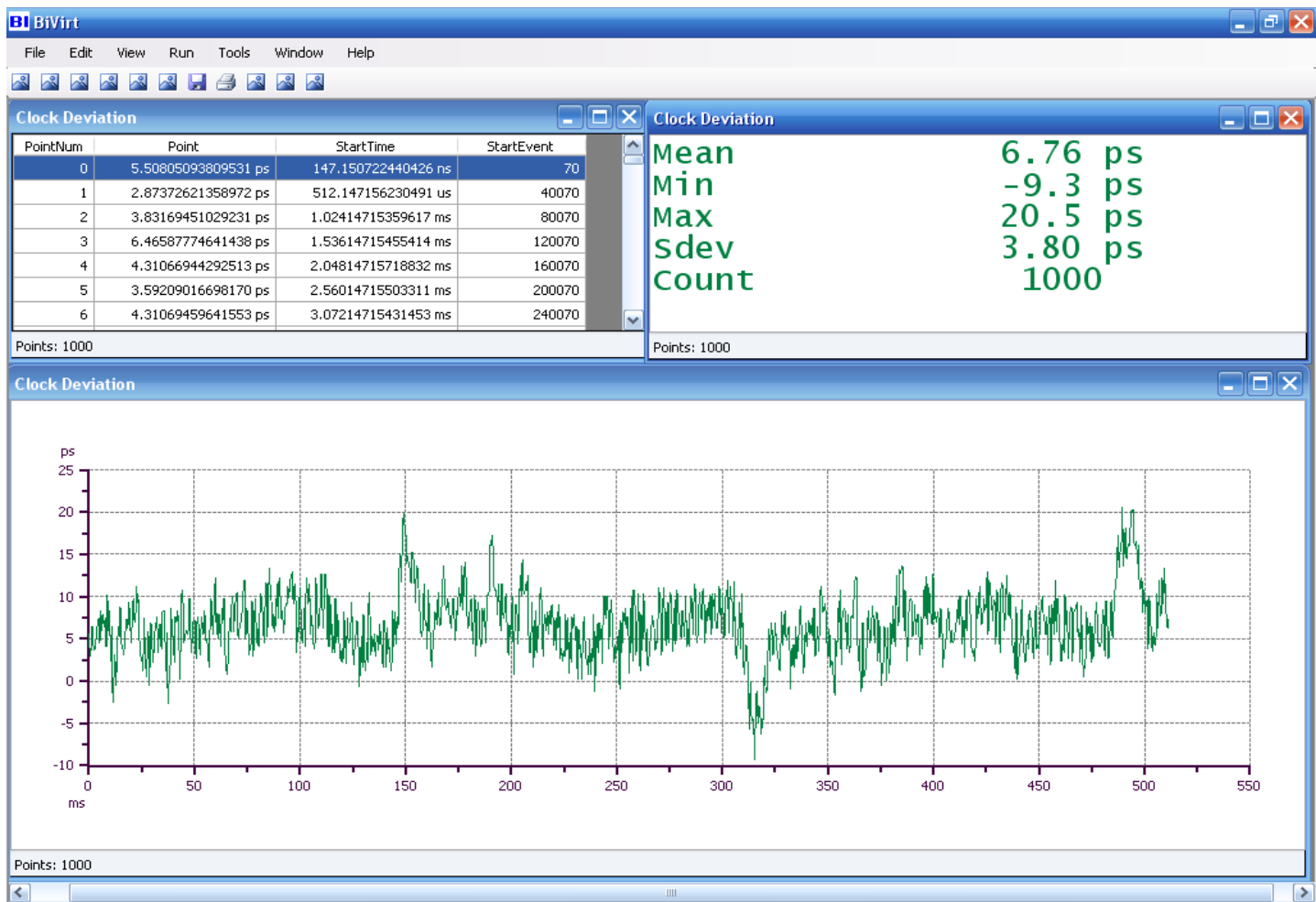


Figure 1: Screen shot of the measurement of an actual clock signal with crosstalk disturbance

HOW DOES IT WORK?

The simplified block diagram on the right shows the key components of the instruments from the user's point of view. The input signal is terminated by 50 ohms to a user-programmable voltage (V_t) and fed to a comparator. The comparator output goes high when the signal crosses a user-programmable threshold voltage (V_{th}). 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 instruments 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 250 ns 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 instruments calculate the measurement results.

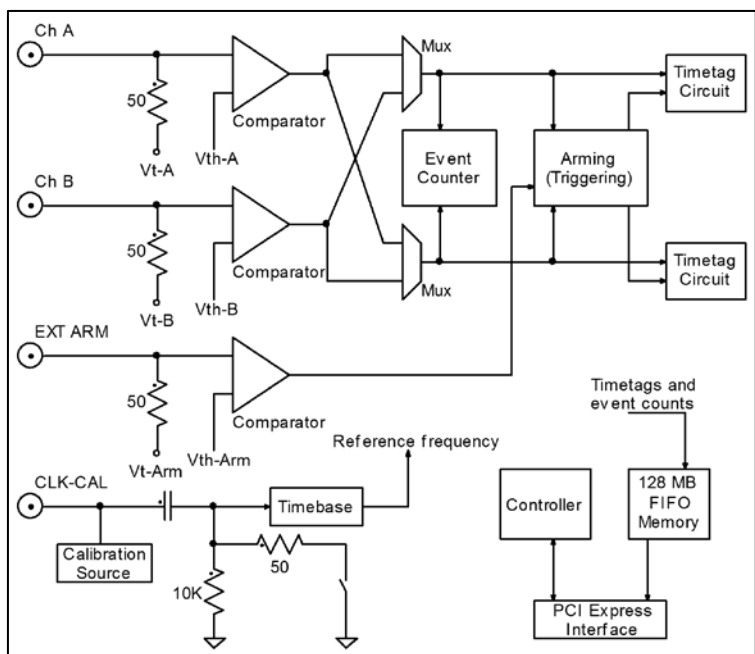


Figure 2: Simplified block diagram

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 250 ns is the minimum time between timetags. That is, for frequencies below 4 MHz 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.

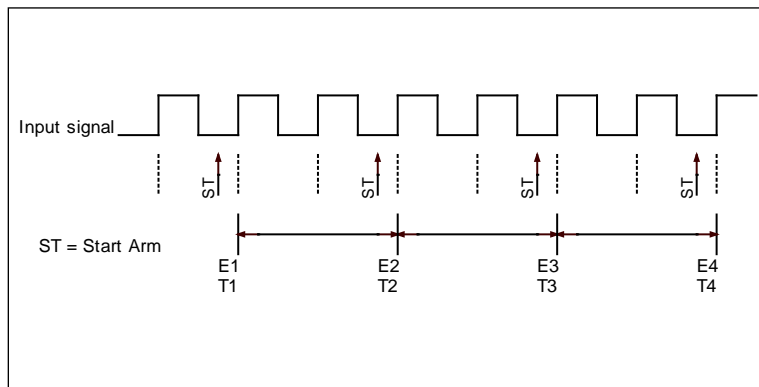


Figure 3: 1C1E functions

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 250 ns 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.

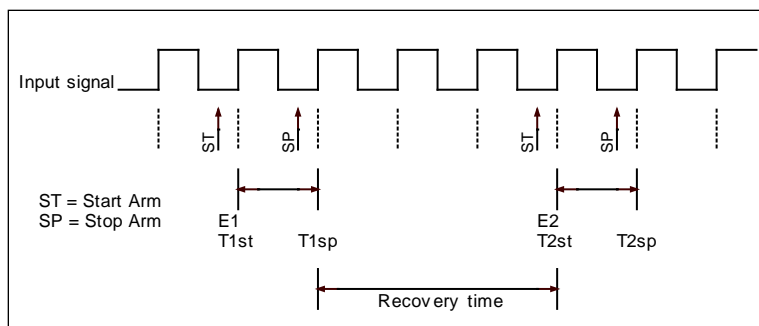


Figure 4: 1C2E functions

Function	Stop Arm	Notes
Period	Next same edge	Measures single periods of the input signal
Pulsewidth	Next opposite edge	Measures individual pulswidths 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 250 ns 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).

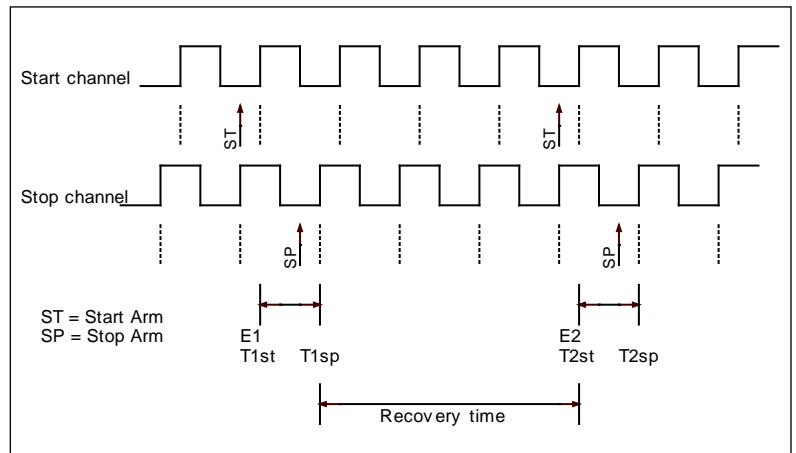


Figure 5: 2C2E functions

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 (T11)
 - Risetime
 - Falltime
- Two-Channel Two-Edge (2C2E) Functions:
 - 2-Ch Time Interval (T12)
- In addition to the measurement results, all functions provide the actual timetag in absolute time and the event count for each measurement (using the Table display)

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:
 - B1200: 0.15 Hz to 2 GHz (4 Gb/s)
 - B1201: 0.15 Hz to 800 MHz (1.6 Gb/s)
- Measurement time ("gate time"): 250 ns to 6.8 s
- 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 1 ms, or 6 digits in 1 μs) regardless of input frequency

- Resolution (in Hz rms):

$$\pm \frac{Freq \times (3ps(rms) + 1.4 \times TriggerError)}{Meastime}$$
- Accuracy (in Hz): $\pm Resolution \pm TimebaseErr$

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:
 - B1200: 500 ps to 6.8 s
 - B1201: 1.25 ns to 6.8 s
- See Frequency Average function for measurement time, number of events, and significant digits
- Resolution (in seconds rms):

$$\pm \frac{Period \times (3ps(rms) + 1.4 \times TriggerError)}{Meastime}$$
- Accuracy (in seconds): $\pm Resolution \pm TimebaseErr$

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: 250 ns to 6.8 s
- Measurement time: 250 ns to 6.8 s (can comprise multiple periods of the input signal)
- Frequency range:
 - B1200: 0.15 Hz to 2 GHz (4 Gb/s)
 - B1201: 0.15 Hz to 800 MHz (1.6 Gb/s)
- Number of events during measurement: 1 to 4.29 billion (limits measurement time to 2.14s at 2GHz)
- Resolution:

$$\pm 3 ps(rms) \pm 1.4 \times TriggerErr$$
- Accuracy: $\pm Resolution \pm TimebaseErr \pm 10 ps$

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:
 - ♦ BI200: 0.15 Hz to 2 GHz (4 Gb/s)
 - ♦ BI201: 0.15 Hz to 800 MHz (1.6 Gb/s)
- Measurement repetition rate: 250 ns to 6.8 s
- Number of events between points: 1 to 4.29 billion (limits measurement repetition to 2.14s at 2GHz)
- Resolution:
 - ± 3 ps(rms) ± 1.4 x TriggerErr
- Accuracy: ±Resolution ± TimebaseErr ± 10 ps

Period A or B

- Measures single periods of the signal
- Type: 1C2E (One-Channel Two-Edge)
- Range:
 - ♦ BI200: 500 ps to 6.8 s
 - ♦ BI201: 1.25 ns to 6.8 s
- Frequency range:
 - ♦ BI200: 0.15 Hz to 2 GHz (4 Gb/s)
 - ♦ BI201: 0.15 Hz to 800 MHz (1.6 Gb/s)
- Time between measurements: 250 ns to 6.8 s
- Resolution: ± 3 ps(rms) ± 1.4 x TriggerErr
- Accuracy: ±Resolution ± TimebaseErr ± 30 ps

Pulsewidth A or B

- Measures pulse widths of the signal
- Type: 1C2E (One-Channel Two-Edge)
- Range: 100 ps to 6.8 s
- Frequency range:
 - ♦ BI200: 0.15 Hz to 2 GHz (4 Gb/s)
 - ♦ BI201: 0.15 Hz to 800 MHz (1.6 Gb/s)
- Time between measurements: 250 ns to 6.8 s
- Resolution: ± 3 ps(rms) ± 1.4 x TriggerErr
- Accuracy:
 - ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 30 ps

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: 200 ps to 6.8 s
- Frequency range:
 - ♦ BI200: 0.15 Hz to 2 GHz (4 Gb/s)
 - ♦ BI201: 0.15 Hz to 800 MHz (1.6 Gb/s)
- Time between measurements: 250 ns to 6.8 s
- Resolution: ± 3 ps(rms) ± 1.4 x TriggerErr
- Accuracy:
 - ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 30 ps

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: 0 ps to 6.8 s

- Frequency range:
 - ♦ BI200: DC to 2 GHz (4 Gb/s)
 - ♦ BI201: DC to 800 MHz (1.6 Gb/s)
- Time between measurements: 250 ns to 6.8 s
- Resolution: ± 3 ps(rms) ± 1.4 x TriggerErr
- Accuracy:
 - ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 20 ps

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: -50 ps to 6.8 s
- Frequency range:
 - ♦ BI200: 0.15 Hz to 2 GHz (4 Gb/s)
 - ♦ BI201: 0.15 Hz to 800 MHz (1.6 Gb/s)
- Time between measurements: 250 ns to 6.8 s
- Resolution:
 - ± 3 ps(rms) ± StartTriggerErr ± StopTriggerErr
- Accuracy:
 - ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 30 ps

Inputs and Outputs

Ch A and B

- Frequency range:
 - ♦ BI200: DC to 2 GHz (4 Gb/s)
 - ♦ BI201: DC to 800 MHz (1.6 Gb/s)
- Minimum pulse width: 100 ps
- Connector: SMA
- Coupling: DC
- Input impedance: 50 Ω into a user programmable termination voltage
- Termination voltage (Vt): -2.0 V to +3.0 V (see restrictions below)
 - ♦ Resolution: 100 μV
 - ♦ Accuracy: 3 mV
- Trigger Threshold voltage (Vth): -3.0 V to +5.0 V (see restrictions below)
 - ♦ Resolution: 200 μV
 - ♦ Accuracy: 6 mV
- Slope: Positive or negative
- Sensitivity: 50 mV rms sine, 50 mVp-p pulse
- Hysteresis – prevents false triggering by having separate threshold levels for rising and falling edges
 - ♦ Range: 1 mV to 50 mV
- Minimum slew rate of input signal
 - ♦ Hysteresis > (20 mV or noise level): no minimum
 - ♦ Hysteresis = 1 mV: 200 V/μs (for 1 Vp-p sinewave, minimum frequency is 62 MHz)
- 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 1.5 V and Vth is 0.5 V, the third equation states that the input signal can range from -4.5 V to +3.5 V. However, the sixth equation restricts the

lower end further to -2.0 V for DC signals and the seventh equation restricts it to -3.5 V for AC signals. For convenience, the instrument software reports the allowed ranges.

- ♦ $-2 \leq V_t \leq +3$
- ♦ $-2 \leq V_t - V_{th} \leq +2$
- ♦ $-4 \leq V_i + V_t - 2V_{th} \leq +4$
- ♦ $-4 \leq V_{th} + V_t \leq +6$
- ♦ $-4 \leq V_i + V_t \leq +6$
- ♦ $-3.5 \leq V_i - V_t \leq +3.5$ (DC)
- ♦ $-5 \leq V_i - V_t \leq +5$ (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)

*With $V_t = 0$, $V_{th} = 0$, maximum input power is +20 dBm

EXTARM Input

- Connector: SMA
- Frequency range: DC to 1.5 GHz
- Minimum pulse width: 300 ps
- Hysteresis: 40 mV typical, fixed
- Setup time: 3 ns ±100 ps (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: SMA
- Input for external timebase reference
 - ♦ Coupling: AC
 - ♦ Impedance: Programmable to 50 Ω or 10 kΩ
 - ♦ Amplitude: 200 mVp-p to 4 Vp-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
 - ♦ $TriggerErr = \frac{\sqrt{(2.5mV)^2 + E_n^2}}{InputSignalSlewRate}$ s rms
 - ♦ E_n = RMS noise of input signal (8 GHz bandwidth)
 - ♦ InputSignalSlewRate = Slew rate of input signal (V/s) at the threshold point
 - For sinewave: $SR = \pi fVpkpk$
 - ♦ Example: With 220 mV (0 dBm), 10 MHz signal, slew rate is 19.8×10^6 and TriggerErr is 130 ps
- TriggerLevelTimeErr
 - ♦ Time error due to threshold uncertainty

- ♦ $TriggerLevelTimeErr = \frac{<6mV}{InputSignalSlewRate}$ s rms
- ♦ Example: For input signal slew rate = 2000 V/μs
TriggerLevelTimeErr = 3 ps
- TimeBaseErr
 - ♦ Fractional Frequency error of timebase reference, times the measurement result

Arming

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

Arming is the enabling of measurements 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 4×10^{15} 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 256 ns to 3.43 s, 12.8 ns resolution
 - ♦ Immediate – run as quickly as possible
 - ♦ By software command
- Number of measurements per block: 1 to 4×10^{15} or “endless”

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: -50 ps to 500 ps
 - ♦ Negative setting allows the measurement of time intervals down to 0 (simultaneous edges on both channels)

Timebase

- Standard internal oscillator:
 - ♦ TCXO (temperature compensated crystal oscillator)
 - ♦ Over full temperature range: ±1 ppm
 - ♦ Aging: ±2 ppm/year

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

Memory

- 128MB on-board
 - ♦ Up to 11 million measurements in 1C1E functions
 - ♦ Up to 8 million measurements 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® and Linux driver
 - ♦ Provides a powerful set of functions for controlling the instruments and for data analysis
 - ♦ Includes tools for high speed reading of the instruments which take advantage of the PCI Express interface without burdening the user with the details
 - ♦ Windows® NT/95/98/2000/XP, 32 bit
 - ♦ Windows® Vista/7/8/10, 32 or 64 bit
 - ♦ Linux with 2.4/2.6 kernels (e.g. Redhat 3, Redhat 5), 32-bit
 - ♦ VBA (for use from excel®, used on some Teradyne testers)
 - ♦ Written in plain C++ for easy porting to other environments

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 of any model simultaneously
- ♦ Compatible with Windows® XP/Vista/7/8/10, 32/64 bit
- ♦ Requires Microsoft™ .NET Framework 3.5 (included)

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
- 256 MB RAM, 100MB 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:	3.3 V @ 2.2 A	12 V @ 0.2 A
From auxiliary power:	5 V @ 0.9 A	12 V @ 1.3 A
- Total power consumption: 30 W 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
- Good ventilation of slots in PC is recommended
- Weight: 9.9 Oz (280 g)

Ordering Information

PN	Description
BI200	BI200 Time Interval Analyzer instrument, 2 GHz, including software
BI201	BI201 Time Interval Analyzer instrument, 800 MHz, including software
Opt-10	Optional high performance timebase (oven oscillator) for BI200 or BI201

