Brilliant Instruments

BI220

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
- 20ps Single-Shot Resolution (11 Digits/s Frequency)
- DC to 400MHz Frequency Range for all Measurement Functions Including Pulsewidth, Plus a Prescaler for Frequency and TIE Measurements to 2.5 GHz
- Up to 1 Million Continuous Zero Dead Time Measurements Per Second
- 1ns Minimum Pulse Width
- Highly Sophisticated and Flexible Arming (Triggering)
- PCI 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 BI220 is a 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 1 million per second continuously to on-board memory, while each of the edges is measured with 20ps 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 BI220 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 interface allowing unlimited acquisition at high rates.

Full-Featured Instrument

The BI220 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 400MHz without any prescaling. This means that you can measure pulses as narrow as 1ns, occurring at frequencies up to 400MHz, or the skew between two signals at 400MHz. There is also a prescaler for each input channel which allows frequency and period measurements to 2.5GHz.

The inputs of the instrument include programmable termination voltages. This feature is seldom found even in the best of the bench-top instruments. You can select by software control either a 1M Ohm impedance to ground, or a 50 ohm load which is terminated to an accurately programmable voltage between -3V and +3V. This allows you to connect ECL, PECL, or CML sources directly to the instrument with the proper loading. The input comparators have a fixed hysteresis of 25mV which is useful 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.

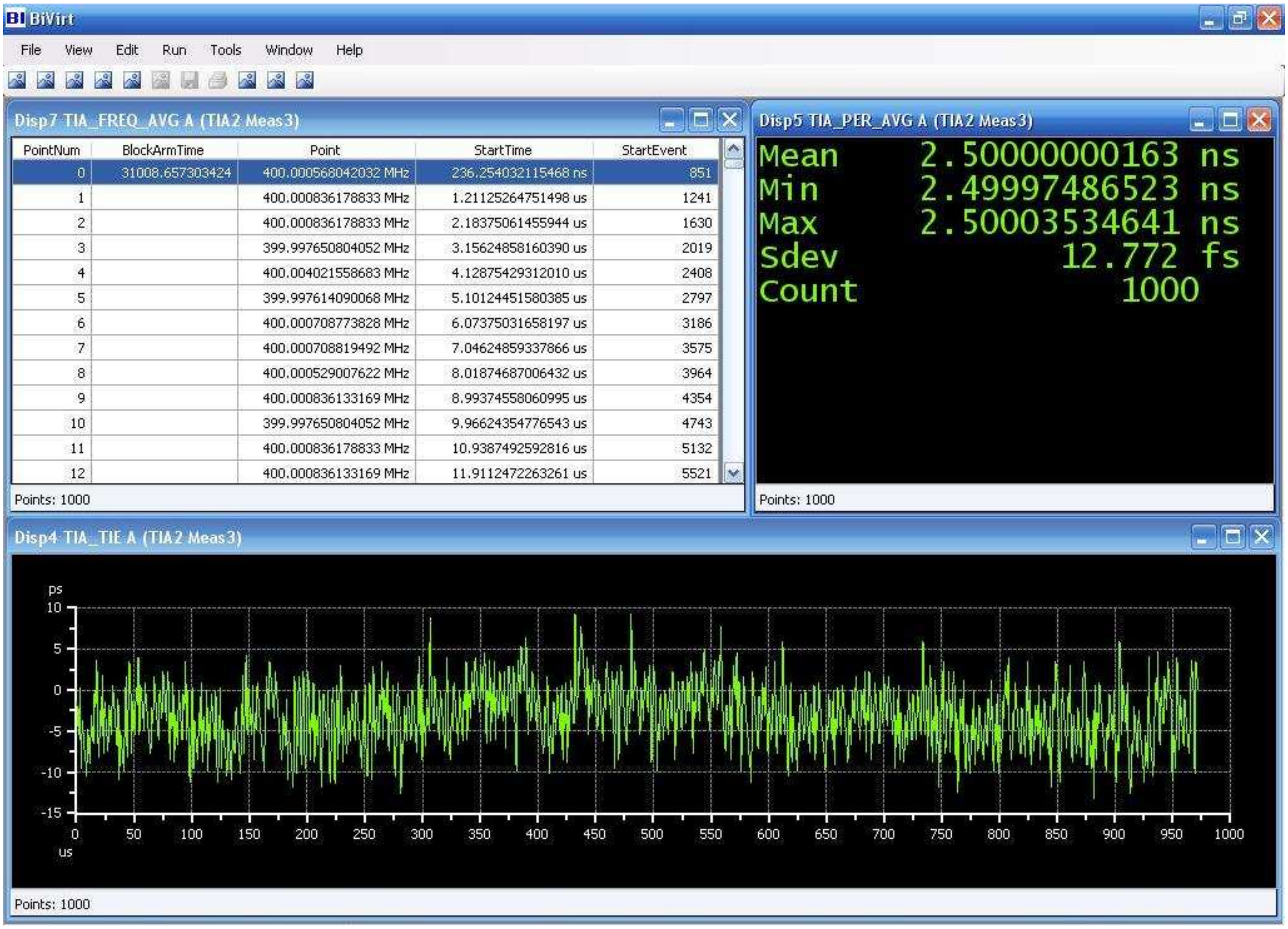
APPLICATIONS

- 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
- Oscillators and crystals – measure frequency, start-up time and time interval error
- Pulse width modulated signals – measure variations over time
- Time stamping of events in real time
- Nuclear physics

Easy to Use Software

The software for the BI220 is designed for ease of use and extremely high performance. The driver software automatically manages the streaming of measurements at the high rates which are possible with the PCI 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. All Brilliant Instruments models use the same software for easy migration between models.

The screen image below is from an actual measurement of a 400 MHz clock. One thousand single channel measurements were taken. The tabular display shows 1000 frequency measurements and the times and event numbers when they were taken. The digital display shows the statistics on period calculations of the same data. The graph display shows the TIE (Time Interval Error) calculations vs. time. Note that all 1000 measurements were taken in less than 1 ms. In addition, the resolution of the instrument is clearly evident with the Y axis of the graph at 5 ps per division.



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 1M ohm to ground or 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 1µs 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 1 million timetags (or pairs of timetags) can be logged per second. From this timetag data, the instrument calculates the measurement results.

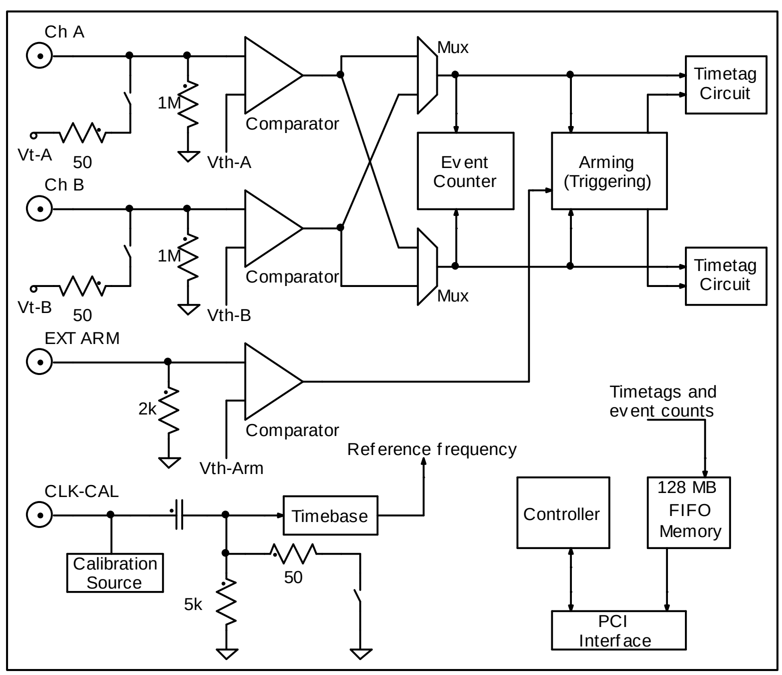


Figure 1: Simplified block diagram

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 1µs is the minimum time between timetags. That is, for frequencies below 1MHz 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 1 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.

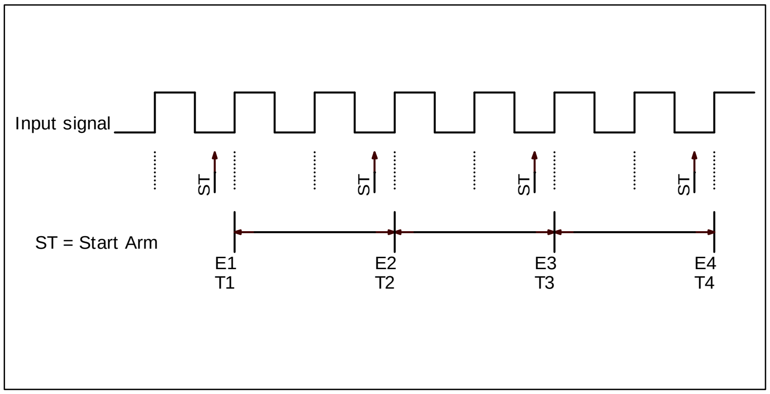


Figure 2: 1C1E functions

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 1µs 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.

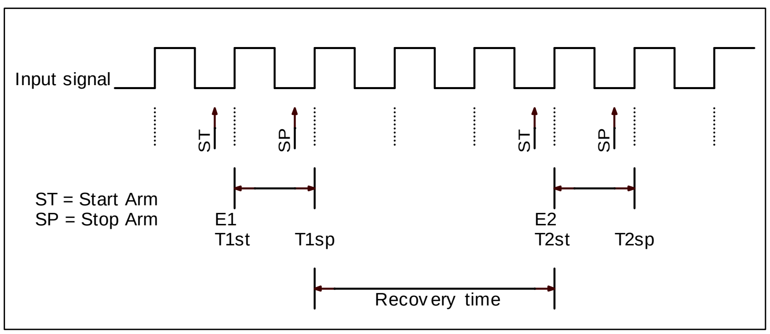


Figure 3: 1C2E functions

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 1µs 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 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).

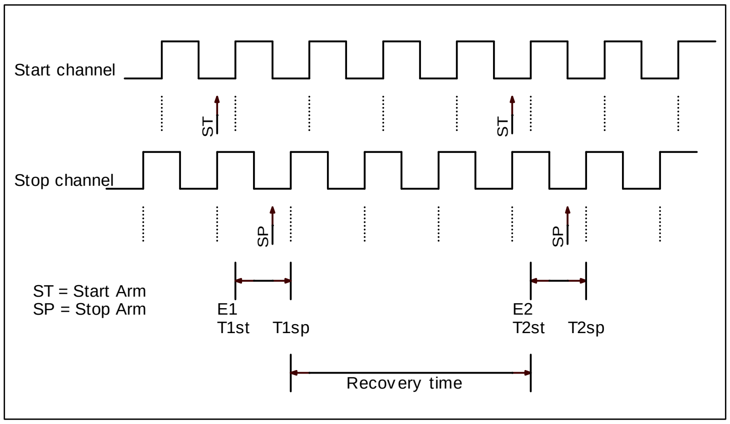


Figure 4: 2C2E functions

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 (direct): 0.15Hz to 400MHz
- Frequency range (prescaled): 50MHz to 2.5GHz
- Measurement time ("gate time"): 1µs to 6.8s
- Number of events for each measurement point: 1 to 4.29 billion
- Number of significant digits: 11 digits/s (8 digits in 1ms, or 5 digits in 1µs) regardless of input frequency
- Resolution (in Hz rms):

$$\pm\frac{Freq\times(20\,ps(rms)+1.4\times TriggerError)}{Meastime}$$

- 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 (direct): 2.5ns to 6.8s
- Range (prescaled): 400ps to 20ns
- See Frequency Average function for measurement time, number of events, and significant digits
- Resolution (in seconds rms):

$$\pm\frac{Period\times(20\,ps(rms)+1.4\times TriggerError)}{Meastime}$$

- 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)
- Frequency range (direct): 0.15Hz to 400MHz
- Frequency range (prescaled): 50MHz to 2.5GHz
- Range: 1µs to 6.8s
- Measurement time: 1µs to 6.8s (can comprise multiple periods of the input signal)
- Number of events during measurement: 1 to 4.29 billion
- Resolution:

  ± 20ps(rms) ± 1.4 x TriggerErr
- Accuracy: ±Resolution ± TimebaseErr ± 50ps

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 (direct): 0.15Hz to 400MHz
- Frequency range (prescaled): 50MHz to 2.5GHz
- Measurement repetition rate: 1µs to 6.8s
- Number of events between points: 1 to 4.29 billion
- Resolution:

  ± 20ps(rms) ± 1.4 x TriggerErr
- Accuracy: ±Resolution ± TimebaseErr ± 50ps

Period A or B

- Measures single periods of the signal
- Type: 1C2E (One-Channel Two-Edge)
- Range: 2.5ns to 6.8s
- Frequency range: 0.15Hz to 400MHz
- Time between measurements: 1µs to 6.8s
- Resolution: ± 20ps(rms) ± 1.4 x TriggerErr
- Accuracy: ±Resolution ± TimebaseErr ± 100ps

Pulsewidth A or B

- Measures pulse widths of the signal
- Type: 1C2E (One-Channel Two-Edge)
- Range: 1.25ns to 6.8s
- Frequency range: 0.15Hz to 400MHz
- Time between measurements: 1µs to 6.8s
- Resolution: ± 20ps(rms) ± 1.4 x TriggerErr
- Accuracy:

  ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 100ps

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: 1.25ns to 6.8s
- Frequency range: 0.15Hz to 400MHz
- Time between measurements: 1µs to 6.8s
- Resolution: ± 20ps(rms) ± 1.4 x TriggerErr
- Accuracy:

  ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 100ps

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 400MHz
- Time between measurements: 1µs to 6.8s
- Resolution: ± 20ps(rms) ± 1.4 x TriggerErr
- Accuracy:

  ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 100ps

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: -500ps to 6.8s
- Frequency range: 0.15Hz to 400MHz
- Time between measurements: 1µs to 6.8s
- Resolution:

  ± 20ps(rms) ± StartTriggerErr ± StopTriggerErr
- Accuracy:

  ±Resolution ± TimebaseErr ± TriggerLevelTimeErr ± 100ps

Inputs and Outputs

Ch A and B

- Direct input (no prescaler):
  - Frequency range: DC to 400MHz
  - Minimum pulse width: 1ns
  - Coupling: DC
  - Input impedance: 1MΩ to ground or 50Ω into a user programmable termination voltage
  - Sensitivity: 50mV rms sine, 50mVp-p pulse
- Prescaled input:
  - Frequency range: 50MHz to 2.5GHz
  - Minimum pulse width: 200ps
  - Coupling: AC
  - Input impedance: 50Ω into a user programmable termination voltage
  - Sensitivity: 30mV rms sine, 30mVp-p pulse
- Connector: SMA
- Termination voltage (Vt): -3.0V to +3.0V
  - Resolution: 100µV
  - Accuracy: 10mV
- Trigger Threshold voltage (Vth): -5.0V to +5.0V
  - Resolution: 200µV
  - Accuracy: 10mV
- Input voltage range:
  - Operating: -5.0V to +5.0V
  - Maximum (1MΩ): -30V to +30V
  - Maximum (50Ω): -5.0V to 5.0V DC, or 5 Vrms AC
- Slope: Positive or negative
- Hysteresis – prevents false triggering by having separate threshold levels for rising and falling edges: 25mV

EXTARM Input

- Connector: SMA
- Frequency range: DC to 400MHz
- Minimum pulse width: 1ns
- Hysteresis: 40mV typical, fixed
- Setup time: 5ns
- Impedance: 2kΩ to ground (no programmable termination)
- Coupling: DC
- Trigger Threshold voltage (Vth): -5.0V to +5.0V
  - Resolution: 200µV
  - Accuracy: 10mV
- Input voltage range:
  - Operating: -5.0V to +5.0V
  - Maximum: -10V to +10V
- Slope: Positive or negative

EXTCLK Input / CAL Output

- Connector: SMA
- Input for external timebase reference
  - Coupling: AC

- Impedance: Programmable to 50Ω or 5kΩ
- Amplitude:
  - Square wave – 400mVp-p to 4Vp-p
  - Sine wave – 1Vp-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 (1GHz bandwidth)
  - InputSignalSlewRate = Slew rate of input signal (V/s) at the threshold point
- TriggerLevelTimeErr
  - Time error due to threshold uncertainty
  - $TriggerLevelTimeErr = \frac{<10mV}{InputSignalSlewRate}$ s rms
  - Example: For input signal slew rate = 100V/µs TriggerLevelTimeErr = 100ps
- 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 or falling edge
  - By Time – every 1µs 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 or falling edge
  - By Time – every 1µs 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 can be selected to occur either before or after the start edge of the signal

Timebase

- Standard internal oscillator:
  - Over full temperature range: ±3 ppm
  - Aging: ±1 ppm/year
- Optional internal 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

- 128MB on-board
  - Up to 11 million points in 1C1E functions
  - Up to 8 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® and Linux driver
  - Provides a 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 interface without burdening the user with the details
  - Compatible with Linux 2.4/2.6 kernels and with Windows® NT/95/2000/XP/Vista
  - 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® 2000/XP/Vista 32-bit
- Requires .NET Framework 2.0 (available free from Microsoft™)

Computer Requirements

- One 32-bit 33 or 66 MHz PCI slot
- Size: 4.0"x5.2" (10.2x13.2cm) excluding bracket
- 256MB RAM, 50MB 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 from PCI bus (typical):
  - 3.3V @ 4.8A 5V @ 0.6A 12V @ 0.3A
- Total power consumption: 22W typical
- Operating temperature range: 0°C to 45°C
- Good ventilation of slots in PC is recommended
- Weight: 5 Oz (140 g)

*Specifications are subject to change without notice

2/8/11