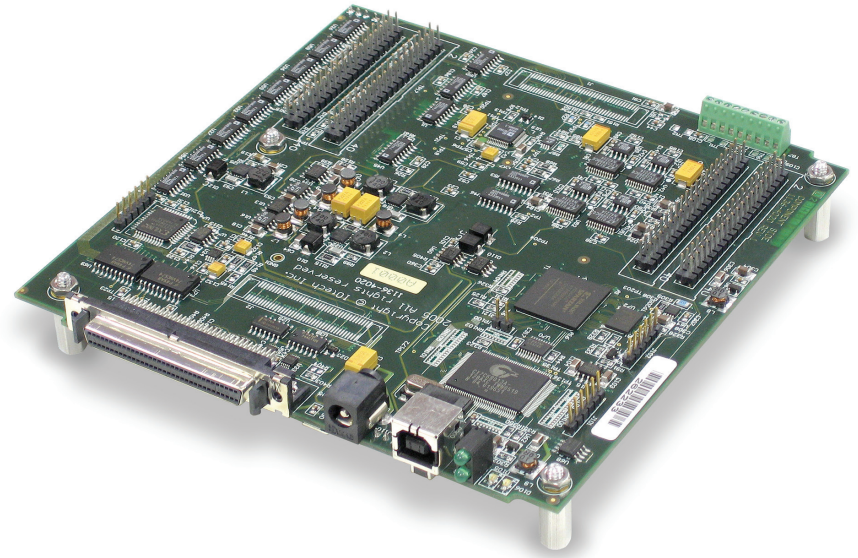
# USB-2500 Series

## High-Speed Multifunction DAQ Boards



*The USB-2500 Series boards are high-Speed Multifunction DAQ Boards designed for OEM and embedded applications*

## Overview

The USB-2500 Series offers high-speed, multifunction data acquisition in a low-cost, board-only design.

Each board offers synchronous and concurrent voltage input, temperature input, waveform output, counter input, quadrature encoder input, timer output, and digital I/O.

Everything necessary to begin acquiring, viewing, and storing data is included with the USB-2500 Series, including comprehensive software support.

USB-2500 Series devices feature a 16-bit/1 MHz A/D converter, up to 64 analog inputs, up to four 16-bit, 1 MHz analog outputs, 24 high-speed digital I/O, 2 timer outputs, and four 32-bit counters. All analog I/O, digital I/O, and counter/timer I/O can operate synchronously and simultaneously, guaranteeing deterministic I/O among all signal types.

Unique to the USB-2500 Series is a low-latency, highly deterministic control output mode that operates independent of the PC. In this mode digital, analog, and timer outputs can respond to analog, digital, and counter inputs as fast as 2 µs; at least 1,000 times faster than other products that rely on the PC for decision making.

## Features

- 8 to 64 analog inputs
- 16-bit resolution
- Up to 4 analog outputs
- 4 thermocouple inputs
- 24 digital I/O
- 4 counter inputs with quadrature encoding support
- 4 thermocouple inputs
- 1 MS/s sample rate
- Synchronous scanning
- Low-latency setpoint control mode
- Designed for OEM and embedded applications

### Supported Operating Systems

- Windows 11/10/8/7/Vista®/ XP 32/64-bit

## Analog Input

The USB-2500 Series has a 16-bit, 1 MHz A/D coupled with 16 single-ended, 8 differential analog inputs (USB-2523 and USB-2527 models), or 64 single-ended/32 differential analog inputs (USB-2533 and USB-2537 models).

The analog input ranges are software configurable. Each channel can be configured for a different range, as well as for single-ended or differential bipolar input, or thermocouple input.

Four of the analog inputs can be configured to measure thermocouples. Built-in cold-junction sensors are provided for each of the screw-terminal connectors, and any TC type can be attached to any channel.

**USB-2500 Series Selection Chart**

| | Analog Inputs | Analog Outputs | DIO | Counters | Timers |
|---|---|---|---|---|---|
| USB-2523 | 16 SE/8 DIFF | 0 | 24 | 4 | 2 |
| USB-2527 | 16 SE/8 DIFF | 4 | 24 | 4 | 2 |
| USB-2533 | 64 SE/32 DIFF | 0 | 24 | 4 | 2 |
| USB-2537 | 64 SE/32 DIFF | 4 | 24 | 4 | 2 |

**Note**: Up to four analog inputs can be used to measure thermocouples.

# USB-2500 Series

## Features

## Analog Output

**(USB-2527 and USB-2537 Only)**

Four 16-bit output channels are provided, with a range of –10 V to +10 V. The maximum update rate is dependent on several factors. Typically, with the A/D operating at full 1 MS/s rates, one analog output can be continuously updated at 1 MHz, two outputs at 500 kHz, and four outputs at 250 kHz. A program can asynchronously output a value to any of the D/As for non-waveform applications. Each output can also be used in a control mode, where the output level is dependent on whether an associated analog, digital, or counter input is above or below a user-specified limit condition.

When used to generate waveforms, users can select from the following clock sources to pace each output:

- **Asynchronous internal clock: t**he on-board programmable clock can generate updates ranging from 1 MHz to once every 19 hours, independent of acquisition rate.
- **Synchronous internal clock: t**he rate of analog output update can be synchronized to the acquisition rate derived from 1 MHz to once every 19 hours.
- **Asynchronous external clock**: a user-supplied external input clock can be used to pace the D/A, entirely independent of analog inputs.
- **Synchronous external clock**: a user-supplied external input clock can pace both the D/A and the analog input.

A separate clock source can be configured for each output.

## Digital I/O

Twenty-four TTL-level digital I/O lines are provided as three 8-bit ports. Each port programmed for input can be scanned with analog input channels, or can be asynchronously accessed via the PC at any time, including during the acquisition.

The digital inputs can be scanned either at the start of each scan sequence or scanned synchronously with each analog input channel.

- When scanned at the start of a scan, the rate is dependent on the number of input channels and the delay period. Example: if eight inputs are enabled with 0 delay period, the digital inputs are scanned once per 8 µs, or 125 kHz.
- When scanned synchronously with the analog inputs, digital inputs are scanned synchronously with each analog input. Using the example above, the digital inputs would be scanned at once per µs, or 1 MHz.

When no analog inputs are scanned, the digital inputs can be scanned at a rate up to 12 MS/s.

The low-latency digital output mode allows a digital output to be updated based on the level of an analog, digital, or counter input. Users associate a digital output bit with a specific input, and specifies the level of the input where the digital output changes state. The response time is dependent on the number of input channels being scanned; a typical range is 2 µs to 6 µs.

## Pattern Generation

Two of the 8-bit ports can be used to generate a 16-bit digital pattern at up to 1 MHz. The digital pattern can be read from PC RAM or a file on the hard disk. Digital pattern generation is clocked using the same sources as described with analog output.

## Counter Input

Four 32-bit counters accept frequency inputs up to 20 MHz, and can be configured in a variety of modes including counter, period, pulse width, time between edges, or multi-axis quadrature encoder.

Counter inputs can be read asynchronously under program control, or synchronously as part of an analog and digital scan group based either on an internal programmable timer, or an external clock source. Counters used for Z-channel encoding or as mapped channels must be read synchronously.

The counters can also be configured as mapped channels and used to gate or decrement the counter, or latch the current count to the count register.

## Quadrature Encoders

Quadrature encoders with up to 2 billion pulses per revolution, 20 MHz input frequencies, and x1, x2, x4 count modes are supported. Two encoder channels are supported with only A phase and B phase signals. One channel is supported with A phase, B phase, and Z index signals.

## Timer Output

Two 16-bit timer outputs can be used to generate different square waves with a programmable frequency range from 16 Hz to 1 MHz.

## Synchronous I/O

The USB-2500 Series can make analog measurements and read digital and counter inputs, while synchronously generating up to four analog outputs as well as digital pattern outputs. Digital and counter inputs do not affect the overall A/D rate because they use no time slot in the scanning sequencer.

## Input Scanning

Several scanning modes are available to address a wide variety of applications. The user can load the scan buffer with any combination of analog input channels. Each channel in the scan buffer is measured sequentially at 1 µs per channel. The user can specify that the sequence repeat immediately or after a programmable delay. For example, in the fastest mode with a 0 delay, a single analog channel can be scanned continuously at 1 MS/s; two analog channels can be scanned at 500 kS/s each; 16 analog input channels can be scanned at 62.5 kS/s.

The digital and counter inputs can be read synchronously with software as part of a scan group, or asynchronously at anytime before, during, or after an analog input scan sequence. Asynchronous mode is not deterministic as to exactly when the digital or counter input is read relative to an analog input channel.

# USB-2500 Series

## Features

### Output Timing

The digital and analog outputs can be updated asynchronously or synchronously in several modes.

In asynchronous mode, digital and analog outputs can be updated at anytime before, during, or subsequent to an analog input sequence. The maximum update rate is non-deterministic and entirely dependent on the PC processor speed, the operating system, and programming environment.

With synchronous output modes, the outputs can be updated continuously from the PC, or as the direct result of input from an analog, digital, or counter channel. When updated from the PC, the user can specify the rate by which the output is updated in 20.83 ns intervals, and outputs are updated synchronously at a maximum rate of 1 µs.

### External Power Option

The USB-2500 Series are designed with an external power connector if a user wants to power the board with the optional PS-9V1AEPS-2500 power supply.

The PS-9V1AEPS-2500 power supply plugs into a standard 120 VAC outlet and supplies 9 VDC, 1 A power.

### Low-Latency Setpoint Control Mode

The low-latency setpoint control is a synchronous output method in which a digital, analog, or timer output is associated with any analog, digital, or counter input. The output state or level is determined by the level or state of an associated input state or level.

For example, a digital output can be programmed for logic 1 when an analog input exceeds a certain value or a frequency input exceeds a certain rate.

An output status channel can be specified in the input scan sequence buffer so that users can correlate output state changes to their respective input channels within their data buffers and files.

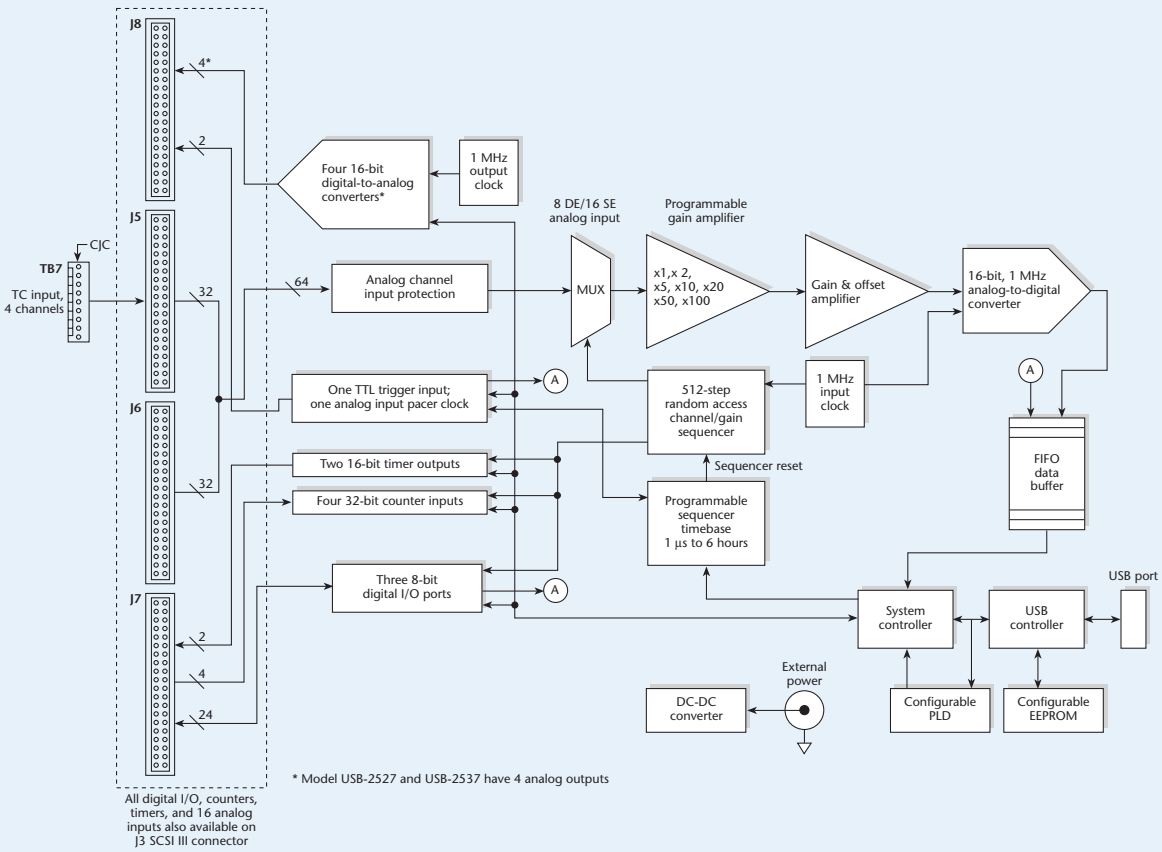
The advantage of this mode as compared to other boards is the response time can be in the range of 2 to 20 µs, vs. 1000 or more microseconds when using boards from other suppliers.

### Calibration

The USB-2500 Series is factory-calibrated using a NIST-traceable calibration process. Specifications are guaranteed for one year. For calibration beyond one year, return the device to the factory for recalibration.

The USB-2500 Series also supports field calibration so that users can calibrate a device locally.

### USB-2500 Series Block Diagram

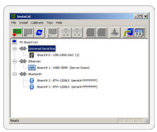
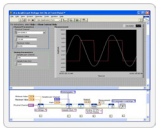


# USB-2500 Series

## Software

## Software Support

The USB-2500 Series is supported by the software in the table below.

| Ready-to-Run Applications | | |
|---|---|---|
| InstaCal |  | An interactive installation, configuration, and test utility for MCC hardware. Windows OS<br>InstaCal is included with the free MCC DAQ Software bundle. |
| TracerDAQ™ and TracerDAQ Pro |  | Virtual strip chart, oscilloscope, function generator, and rate generator applications used to generate, acquire, analyze, display, and export data. Supported features may vary by hardware. The Pro version provides enhanced features. Windows OS<br>TracerDAQ is included with the free MCC DAQ Software bundle.<br>TracerDAQ Pro is available as a purchased software download. |
| **General-Purpose Programming Support** | | |
| Universal Library (UL) |  | Library for developing applications in C, C++, VB, C# .Net, VB .Net, and Python. Windows OS<br>The UL is included with the free MCC DAQ Software bundle. |
| **Application-Specific Programming Support** | | |
| ULx for NI LabVIEW™ |  | A comprehensive library of VIs and example programs for NI LabVIEW that is used to develop custom applications that interact with most MCC devices. Windows OS<br>ULx for NI LabVIEW is included with the free MCC DAQ Software bundle. |
| DASYLab® |  | Icon-based data acquisition, graphics, control, and analysis software that allows users to create complex applications in minimal time without text-based programming. Windows OS<br>DASYLab is available as a purchased software download. |
| MATLAB® Driver |  | High-level language and interactive environment for numerical computation, visualization, and programming. The Mathworks Data Acquisition Toolbox™ allows users to acquire data from most MCC PCI and USB devices.<br>Visit www.MathWorks.com for more information about the Data Acquisition Toolbox. |

# USB-2500 Series

## Specifications

### Analog Input

**A/D converter type**: Successive approximation
**Resolution:** 16 bit
**Sample rate:** 1 MHz max
**Nonlinearity**
**Integral:** ±2 LSB max
**Differential:** ±1 LSB max
**Channels**: 16 single-ended or 8 differential
**Over-voltage protection**: ±30 V without damage
**Voltage measurement speed**: 1 µs per channel
**Ranges**: ±10 V, ±5 V, ±2 V, ±1 V, ±0.5 V, ±0.2 V, ±0.1 V; software or sequencer selectable on a per-channel basis
**Input impedance**: 10 MΩ single-ended; 20 MΩ differential
**Total harmonic distortion**: –80 dB, typ for ±10 V range, 1 kHz fundamental
**Signal to noise and distortion**: 72 dB, typ for ±10 V range, 1 kHz fundamental
**Bias current**: 40 pA typ (0 to 35 ˚C)
**Crosstalk**: –67 dB typ DC to 10 kHz
**Common mode rejection**: –70 dB typ DC to 1 kHz
Maximum usable input voltage + common mode voltage (CMV +$V_{in}$)
Range ±10 V, ±5 V, ±2 V, ±1 V, ±0.5 V: 10.5 V max
Range ±0.2 V, ±0.1 V: 2.1 V max

### Thermocouples

| TC Type | Thermocouple range (°C) | Accuracy (±°C) | Noise typical (±°C) |
|---|---|---|---|
| I | –200 to +760 | 1.7 | 0.2 |
| K | –200 to +1200 | 1.8 | 0.2 |
| T | –200 to +400 | 1.8 | 0.2 |
| E | –270 to +650 | 1.7 | 0.2 |
| R | –50 to +1768 | 4.8 | 1.5 |
| S | –50 to +1768 | 4.7 | 1.5 |
| N | –200 to +1300 | 2.7 | 0.3 |
| B | +300 to +1400 | 3.0 | 1.0 |

Assumes 16384 oversampling applied, CMV = 0.0 V, 60 minute warm-up, still environment, and 25 ˚C ambient temperature; excludes thermocouple error; $TC_{IN}$ = 0 °C for all types except B (1000 ˚C), PS-9VIAEPS-2500 for External Power.

### Accuracy

| Voltage Range* | Accuracy ±(% of reading + % Range) 23 °C, ± °10 ±C, 1 year | Temperature Coefficient ±(ppm of reading + ppm Range)/ °C –30 °C to 13 °C and 33 °C to 70 °C | Noise** (cts RMS) |
|---|---|---|---|
| –10 V to 10 V | 0.031% + 0.008% | 14 + 8 | 2.0 |
| –5 V to 5 V | 0.031% + 0.009% | 14 + 9 | 3.0 |
| –2 V to 2 V | 0.031% + 0.010% | 14 + 10 | 2.0 |
| –1 V to 1 V | 0.031% + 0.02% | 14 + 12 | 3.5 |
| –500 mV to 500 mV | 0.031% + 0.04% | 14 + 18 | 5.5 |
| –200 mV to 200 mV | 0.036% + 0.05% | 14 + 12 | 8.0 |
| –100 mV to 100 mV | 0.0442% + 0.10% | 14 + 18 | 14.0 |

* Assumes diff input single channel scan, 1 MHz scan rate, unfiltered, CMV=0.0 V, 30 min warm-up, exclusive of noise, range is +FS to –FS.
** Noise reflects 10,000 samples at 1 MHz, typical, differential short.

### Analog Outputs

(USB-2527 and USB-2537 only)
Analog outputs are updated synchronously relative to scanned inputs, and clocked from either an internal or external clock source. Analog outputs can also be updated asynchronously, independent of any other scanning. Streaming from disk or memory is supported for continuous waveform output.
**Channels:** Four DAC channels – DAC0, DAC1, DAC2, DAC3
**Resolution:** 16 bits
**Data buffer:** PC-based memory
**Output voltage range:** ±10 V
**Output current**: ±1 mA max; sourcing more current (1 to 10 mA) may require a PS-9VIAEPS-2500 power adapter option
**Offset Error:** ±0.0045 V max
**Digital feedthrough:** <10 mV when updated
**DAC analog glitch:** <12 mV typ at major carry
**Gain Error:** ±0.01%
**Update rate:** 1 MHz max, 19 hours min (no minimum with external clock); resolution 20.83 ns
**Settling time:** 2 µs to rated accuracy
**Pacer sources**
Four programmable sources: Onboard D/A clock, independent of scanning input clock; onboard scanning input clock; external D/A input clock, independent of external scanning input clock; external scanning input clock
**Trigger sources**: start of input scan

### Digital I/O

**I/O channels**: 24
**Ports**: three 8-bit; each port is programmable as input or output
**Input scanning modes**: Asynchronous, under program control at any time relative to input scanning, and synchronous with input scanning
**Input characteristics**: 220 Ω series resistor, 20 pF to common
**Logic keeper circuit**: Holds the logic value to 0 or 1 with no external driver
**Input protection**: ±15 kV ESD clamp diodes parallel
**Input levels**
**Low:** 0 to 0.8 V
**High:** +2.0 V to +5.0 V
**Output Levels**
**Low:** < 0.8 V
**High:** >2.0 V
**Output current**: Output 1.0 mA per pin; sourcing more current may require a PS-9VIAEPS-2500 power adapter option
**Digital input pacing**: Onboard clock, external scan clock
**Digital output pacing**: Onboard output scan clock (independent of input scan clock), onboard input scan clock, external output scan clock (independent of external input scan clock, external input scan clock)
**Digital input trigger sources:** see "Trigger Sources and Modes" on page 6
**Sampling/update rate**: 4 MHz max; rates up to 12 MHz are sustainable on some platforms.
**Pattern generation output**: Two of the 8-bit ports can be configured for 16-bit pattern generation. The pattern can also be updated synchronously with an acquisition at up to 4 MHz.

# USB-2500 Series

## Specifications

### Counter

Counter inputs can be scanned synchronously along with analog and digital scanned inputs, based on an internal programmable timer, or an external clock source. Each counter can be configured for counter, period, pulse width, time between edges, or multi-axis quadrature encoder modes.
**Channels:** 4 independent
**Resolution**: 32-bit
**Input frequency:** 20 MHz max
**Input signal range:** –5 V to +10 V
**Input characteristics:** 10 kΩ pull-up, ±15 kV ESD protection
**Trigger level:** TTL
**Minimum pulse width:** 25 ns high, 25 ns low
**Debounce times:** 16 selections from 500 ns to 25.5 ms; positive or negative edge sensitive; glitch detect mode or debounce mode
**Time-base accuracy:** 50 ppm (0 to 50 ˚C)
**Counter read pacer**: Onboard input scan clock, external input scan clock
**Trigger sources**: see "Trigger Sources and Modes"
**Programmable mode**: Counter. , Period, Pulse width, Timing, Encoder
**Counter mode options:** Totalize, Clear on Read, Rollover, Stop at all Fs, 16- or 32-bit, Gating On, Decrement On
**Period mode options:** Measure x1, 10, 100, or 1000 periods, 16- or 32-bit, time bases to choose from: 20.83 ns, 208.3 ns, 2.083 µs, 20.83 µs, any other channel can gate the period measurement
**Pulse width mode options:** 16- or 32-bit values, 4 time bases to choose from: 20.83 ns, 208.3 ns, 2.083 µs, 20.83 µs, any other channel can gate the pulse width measurement
**Timing mode options:** 16- or 32-bit values, time base is selectable for 20.83 ns, 208.3 ns, 2.083 µs, 20.83 µs
**Encoder mode options:** x1, 2, 4 options, 16- or 32-bit values, Z-channel clearing of counter, any other channel can gate the counter

### Input Sequencer

Analog, digital, and counter inputs can be scanned synchronously based on either an internal programmable timer, or with an external clock source. Analog and digital outputs can be synchronized to either of these clocks.
**Input scan clock sources**
**Internal**:
Analog channels from 1 µs to 19 hours in 20.83 ns steps
Digital channels and counters from 250 ns to 19 hours in 20.83 ns steps
**External**, TTL level input:
Analog channels down to 1 µs min
Digital channels and counters down to 250 ns min
The maximum scan clock rate is the inverse of the minimum scan period.
The minimum scan period is equal to 1 µs × the number of analog channels.
If a scan contains only digital channels, the minimum scan period is 250 ns.
**Programmable parameters per scan:** Channel (random order), gain
**Depth:** 512 locations
**On-board channel-to-channel scan rate**
**Analog:** 1 MHz max
**Digital:** 4 MHz with no analog channels, 1 MHz with analog channels
**External input scan clock rate**:
**Analog:** 1 MHz max
**Digital:** 4 MHz with no analog channels, 1 MHz with analog channels
**Clock signal range**
**Logical zero**: 0 V to 0.8 V
**Logical one**: 2.4 V to 5.0 V
**Minimum pulse width:** 50 ns high, 50 ns low

#### Frequency/Pulse Generators

**Channels:** 2 x 16-bit
**Output waveform:** Square wave
**Output rate:** 1 MHz base rate divided by 1 to 65,535 (programmable)
**High-level output voltage:** 2.0 V min @ -1.0 mA; 2.9 V min @ –400 µA
**Low-level output voltage:** 0.4 V max @ 400 µA

### Trigger Sources and Modes

**Input scan trigger sources**: Five, programmable
Single channel analog hardware trigger, single channel analog software trigger, external-single channel digital trigger, digital pattern trigger, counter/totalizer trigger
**Input scan trigger modes**
**Single channel analog hardware trigger**: the first analog input channel in the scan is the analog trigger channel.
**Input signal range:** -10 to +10 V max
**Trigger level:** Programmable; 12-bit resolution
**Hysteresis:** Programmable; 12-bit resolution
**Latency:** 350 ns typ, 1.3 µs max
**Accuracy:** ±0.5% of reading, ±2 mV offset
**Noise:** 2 mV RMS
**Single channel analog software trigger:** the first analog input channel in the scan is the analog trigger channel.
**Input signal range:** Anywhere within the range of the trigger channel
**Trigger level:** programmable; 16-bit resolution
**Latency:** One scan period max
**External single channel digital trigger**: TTL trigger input
**Input signal range:** -15 V to +15 V
**Trigger level:** TTL level sensitive
**Minimum pulse width:** 50 ns high, 50 ns low
**Latency:** One scan period max
**Digital pattern triggering**: 8 bit or 16 bit pattern triggering on any of the digital ports. Programmable for trigger on equal, not equal, above, or below a value. Individual bits can be masked for a "don't care" condition.
**Latency**: One scan period max
**Counter/totalizer triggering**: counter/totalizer inputs can trigger an acquisition. User can select to trigger on a frequency or on total counts that are equal, not equal, above, or below a value, or within/outside of a window rising/falling edge.
**Latency**: One scan period max

### External Power

**Connector:** Switchcraft#RAPC-712
**Power range:** 6 to 16 VDC; used when the USB port supplies insufficient power or when an independent power supply is desired
**Over-voltage:** 200 V for 10 seconds, max
An optional power supply (MCC p/n PS-9V1AEPS-2500) is required if the USB port cannot supply adequate power. USB 2.0 ports are required by USB 2.0 standards to supply 2500 mW (nominal at 5 V, 500 mA).

### Environmental

**Operating temperature:** –30 to +70 ˚C; Storage **Temperature:** -40 to +80 ˚C
**Relative humidity:** 0 to 95% non-condensing
**Communications speed**: USB 2.0 high-speed mode (480 Mbps) if available, otherwise, USB 1.1 full-speed mode (12 Mbps)
**Acquisition data buffer**: 1 MSample
**Vibration**: MIL STD 810E Category 1 and 10

### Mechanical

**Dimensions (W × D):** 152.4 × 150.62 mm (6.0 × 5.93 in.)
**Weight:** 147 g (0.32 lb)Ordering Information

# USB-2500 Series

## Order Information

## Ordering

| Part No. | Description |
|---|---|
| USB-2523 | Multifunction DAQ board with 16 analog inputs, 1 MS/s sample rate, 24 digital I/O, four counters, and four thermocouples |
| USB-2527 | Multifunction DAQ Board with 16 analog inputs, 1 MS/s sample rate, four analog outputs, 24 digital I/O, four 32-bit counters, and four thermocouples |
| USB-2533 | Multifunction DAQ board with 64 analog inputs, 1 MS/s sample rate, 24 digital I/O, four 32-bit counters, and four thermocouples |
| USB-2537 | Multifunction DAQ board with 64 analog inputs, 1 MS/s sample rate, four 16-bit 1 MS/s analog outputs, 24 digital I/O, four 32-bit counters, and four thermocouples |

## Accessories and Cables

| Part No. | Description |
|---|---|
| TB-100 | Termination board with screw-terminals; connects via a CA-68-3R, CA-68-3S, or CA-68-6S cable. |
| TB-101 | Termination board with screw terminals; mates directly with the board, and includes mounting stand-offs. |
| PS-9VIAEPS-2500 | 90 to 264 VAC External power supply. Requires CA-1 (US) or CA-216 (EU) cable. |
| CA-1 | Required cable for use with PS-9VIAEPS-2500. US version |
| CA-216 | Required cable for use with PS-9VIAEPS-2500. EU version |
| CA-68-3R | 68-conductor ribbon expansion cable for connection to the TB-100. |
| CA-68-3S, CA-68-6S | 68-conductor shielded cable for connection to the TB-100. |
| CA-248 | Ribbon cable, 40-pin header to 37-pin DSUB. |

## Software also Available from MCC

| Part No. | Description |
|---|---|
| TracerDAQ Pro | Out-of-the-box virtual instrument suite with strip chart, oscilloscope, function generator, and rate generator – professional version |
| DASYLab | Icon-based data acquisition, graphics, control, and analysis software |