USB-1616FS

USB-based Analog Input and Digital I/O Module
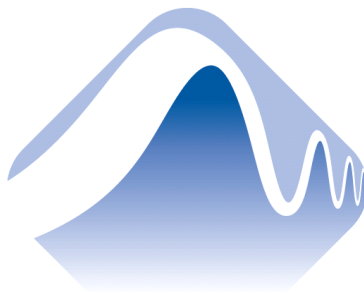
User's Guide

MEASUREMENT COMPUTING™

USB-1616FS

USB-based Analog and Digital I/O

User's Guide

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Table of Contents

About this User's Guide

What you will learn from this user's guide

This user's guide explains how to install, configure, and use the USB-1616FS so that you get the most out of its analog and digital I/O features. This user's guide also refers you to related documents available on our web site, and to technical support resources.

Conventions in this user's guide

For more information on …

Text presented in a box signifies additional information and helpful hints related to the subject matter you are reading.

Caution! Shaded caution statements present information to help you avoid injuring yourself and others, damaging your hardware, or losing your data.

<#:#> Angle brackets that enclose numbers separated by a colon signify a range of numbers, such as those assigned to registers, bit settings, etc.

bold text **Bold** text is used for the names of objects on the screen, such as buttons, text boxes, and check boxes. For example:
1. Insert the disk or CD and click the **OK** button.

italic text *Italic* text is used for the names of manuals and help topic titles, and to emphasize a word or phrase. For example:
The *Insta*Cal installation procedure is explained in the *Quick Start Guide*.
Never touch the exposed pins or circuit connections on the board.

Where to find more information

The following electronic documents provide information relevant to the operation of the USB-1616FS.

- MCC's *Specifications: USB-1616FS* (the PDF version of the *Specifications* chapter in this guide) is available on our web site at www.mccdaq.com/pdfs/USB-1616FS.pdf.
- MCC's *Quick Start Guide* is available on our web site at www.mccdaq.com/PDFmanuals/DAQ-Software-Quick-Start.pdf.
- MCC's *Guide to Signal Connections* is available on our web site at www.mccdaq.com/signals/signals.pdf.
- MCC's *Universal Library User's Guide* is available on our web site at www.mccdaq.com/PDFmanuals/sm-ul-user-guide.pdf.
- MCC's *Universal Library Function Reference* is available on our web site at www.mccdaq.com/PDFmanuals/sm-ul-functions.pdf.
- MCC's *Universal Library for LabVIEW™ User's Guide* is available on our web site at www.mccdaq.com/PDFmanuals/SM-UL-LabVIEW.pdf.

USB-1616FS User's Guide (this document) is also available on our web site at www.mccdaq.com/PDFmanuals/USB-1616FS.pdf.

Introducing the USB-1616FS

Overview: USB-1616FS features

This user's guide contains all of the information you need to connect the USB-1616FS to your computer and to the signals you want to measure.

The USB-1616FS is a USB 2.0 full-speed device supported under popular Microsoft® Windows® operating systems.

The USB-1616FS provides true simultaneous sampling of up to sixteen 16-bit single-ended analog inputs. Simultaneous input sampling is accomplished through the use of one A/D converter per channel. The module features sampling rates of up to 50 kS/s per channel, and up to 9500 S/s per channel throughput for all channels. You can configure the analog input range of each channel independently via software. An on-board temperature sensor lets you monitor your environment temperature.

Eight digital IO lines are independently selectable as input or output. A 32-bit counter can count TTL pulses. A SYNC (synchronization) control line lets you synchronize two USB-1616FS modules to acquire data synchronously from 32 analog inputs.

The USB-1616FS is powered by an external +9 V unregulated power supply that is shipped with the board. Power and USB connectors let you power and control multiple MCC USB Series products from one external power source and one USB port in a daisy chain fashion.

The USB-1616FS is enclosed in a rugged housing that you can mount on a DIN rail or on a bench (Figure 1-1).
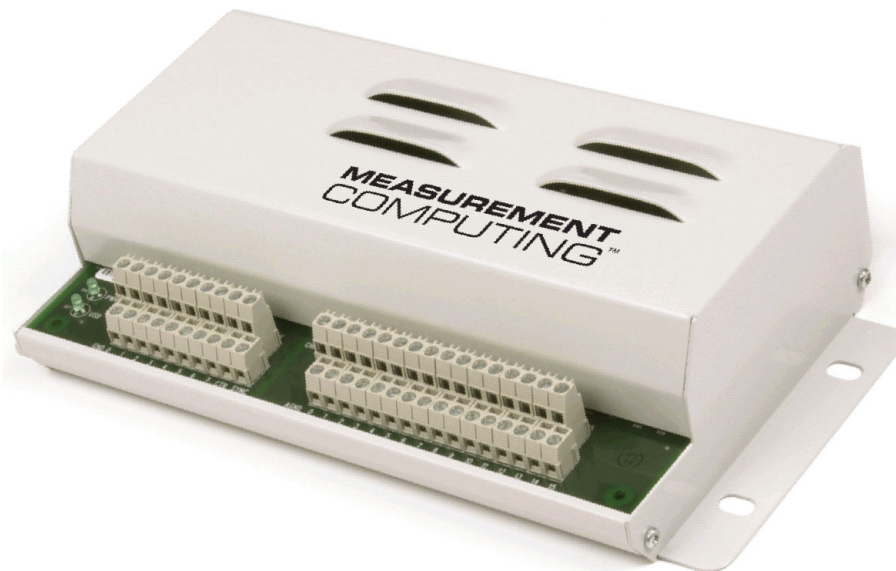
Figure 1-1. USB-1616FS

USB-1616FS block diagram

USB-1616FS functions are illustrated in the block diagram shown here.
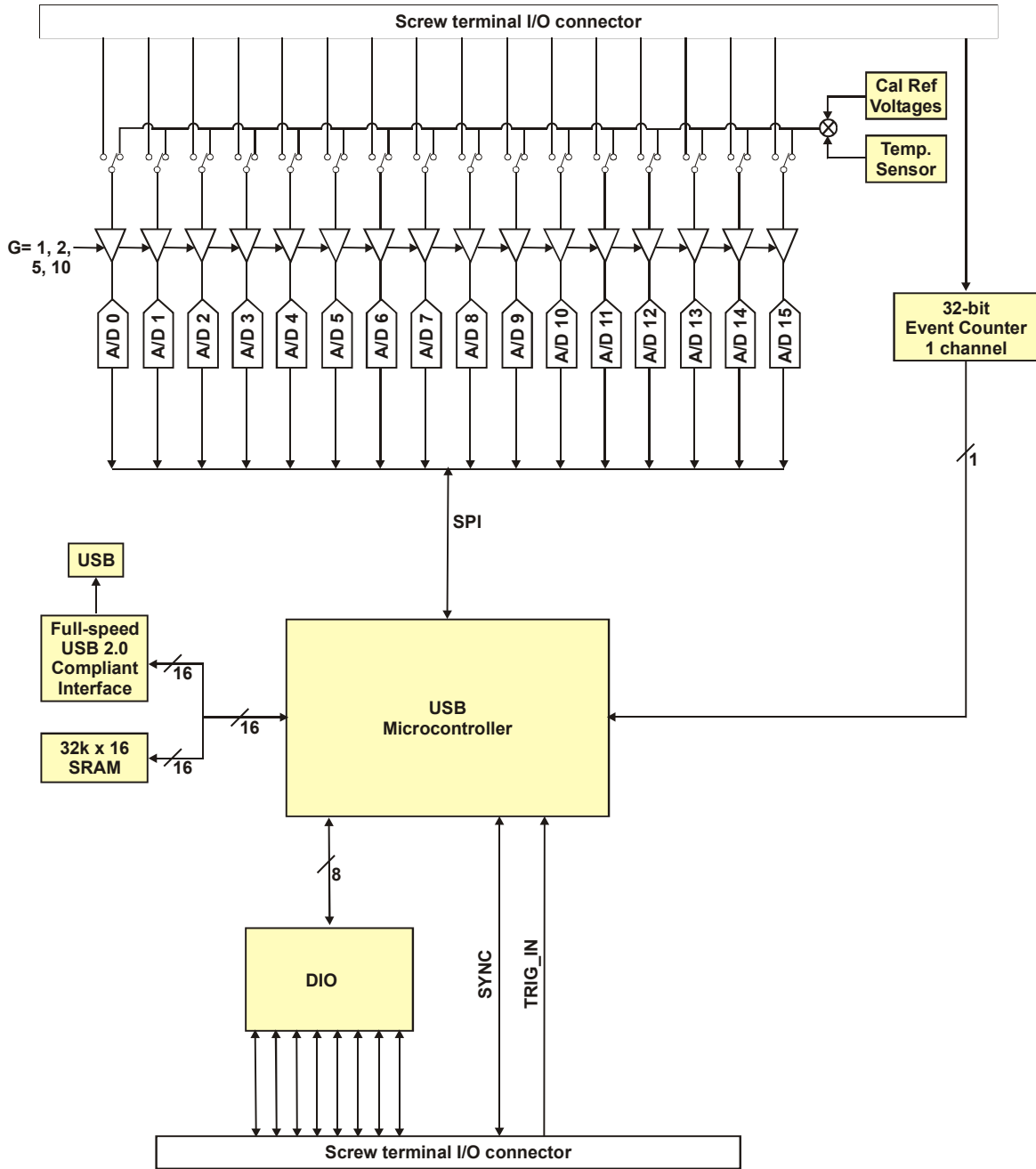
Figure 1-2. USB-1616FS functional block diagram

Software features

For information on the features of *Insta*Cal and the other software included with your USB-1616FS, refer to the *Quick Start Guide* that shipped with your device. The *Quick Start Guide* is also available in PDF at www.mccdaq.com/PDFmanuals/DAQ-Software-Quick-Start.pdf.

Check www.mccdaq.com/download.htm for the latest software version or versions of the software supported under less commonly used operating systems.

Connecting a USB-1616FS to your computer is easy

Installing a data acquisition device has never been easier.

- The USB-1616FS relies upon the Microsoft Human Interface Device (HID) class drivers. The HID class drivers ship with every copy of Windows that is designed to work with USB ports. We use the Microsoft HID because it is a standard, and its performance delivers full control and maximizes data transfer rates for your USB-1616FS. No third-party device driver is required.
- The USB-1616FS is plug-and-play. There are no jumpers to position, DIP switches to set, or interrupts to configure.
- You can connect the USB-1616FS before or after you install the software, and without powering down your computer first. When you connect an HID to your system, your computer automatically detects it and configures the necessary software. You can connect and power multiple HID peripherals to your system using a USB hub.
- You can connect your system to various devices using a standard four-wire cable. The USB connector improves upon serial and parallel port connectors with one standardized plug and port combination.
- Data can flow two ways between a computer and peripheral over USB connections.

Make sure that you have the latest Windows Updates installed for your USB driver, particularly "XP Hotfix KB822603."

Installing the USB-1616FS

What comes with your USB-1616FS shipment?

The following items are shipped with the USB-1616FS.

Hardware

- USB-1616FS
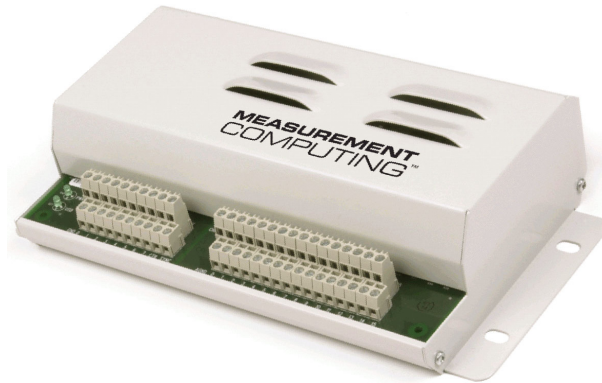
- USB cable (24 AWG VBUS/GND, 2 meter length)

- External power supply and cord (CB-PWR-9V3A) – 9 volt, 3 amp DC power supply

Additional documentation

In addition to this hardware user's guide, you should also receive the *Quick Start Guide* (available in PDF at www.mccdaq.com/PDFmanuals/DAQ-Software-Quick-Start.pdf). This booklet supplies a brief description of the software you received with your USB-1616FS and information regarding installation of that software. Please read this booklet completely before installing any software or hardware.

Unpacking the USB-1616FS

As with any electronic device, you should take care while handling to avoid damage from static electricity. Before removing the USB-1616FS from its packaging, ground yourself using a wrist strap or by simply touching the computer chassis or other grounded object to eliminate any stored static charge.

If your USB-1616FS arrives already damaged, notify Measurement Computing Corporation immediately by phone, fax, or email. For international customers, contact your local distributor where you purchased the USB-1616FS.

- Phone: 508-946-5100 and follow the instructions for reaching Tech Support.
- Fax: 508-946-9500 to the attention of Tech Support
- Email: techsupport@mccdaq.com

Installing the software

Refer to the *Quick Start Guide* for instructions on installing the software on the *Measurement Computing Data Acquisition Software CD*. This booklet is available in PDF at www.mccdaq.com/PDFmanuals/DAQ-Software-Quick-Start.pdf.

Installing the USB-1616FS

Before you connect the USB-1616FS to your computer, connect the external power supply that was shipped with the device.

You can connect up to four MCC USB Series products in a daisy chain configuration to a single USB 2.0 port on your computer. If your system has a USB 1.1 port, you can connect up to two MCC USB Series products.

Connecting the external power supply

Power to the USB-1616FS is provided with the +9 V external power supply (CB-PWR-9V3A). You must connect the external power supply *before* connecting the USB cable to the USB-1616FS and your computer.

To connect the power supply to your USB-1616FS, do the following.

1. Connect the external power cord to the **POWER IN** connector on the rear of the USB-1616FS enclosure. This connector is labeled **IN** on the board.

2. Plug the power supply into a power outlet.

The **PWR** LED illuminates green when +9 V power is supplied to the USB-1616FS. If the voltage supply is less than +6.0 V or more than +12.5 V, the **PWR** LED does not light.

Do not connect external power to the POWER OUT connector

The power connector labeled **POWER OUT** on the enclosure (**OUT** on the board) is used to provide power to an additional MCC USB Series product. If you connect the external power supply to the **POWER OUT** connector, the USB-1616FS does not receive power, and the **PWR** LED does not illuminate.

Connecting the USB-1616FS to your system

To connect the USB-1616FS to your system, do the following.

1. Connect the USB cable that was shipped with the device to the USB connector labeled **USB IN** on the USB-1616FS.

    The USB cable supplied with the USB-1616FS has a higher gauge wire than generic USB cables, and is required for proper enumeration of the USB-1616FS.

2. Connect the other end of the USB cable to a USB port on your computer or to an external USB hub that is connected to your computer. The **PWR LED** illuminates green. The USB cable provides power and communication to the USB-1616FS.

The USB-1616FS installs as a composite device with separate devices attached. When you connect the USB-1616FS for the first time, **Found New Hardware** popup balloons (Windows XP) or dialogs (other Windows versions) display as each USB-1616FS interface is detected. The **USB LED** blinks and then remains lit during this enumeration.

It is normal for multiple dialogs to appear when you connect the USB-1616FS for the first time. For additional information, refer to the "*Notes on installing and using the USB-1616FS*" that was shipped with the USB-1616FS.

If you are running Windows XP and connect the USB-1616FS to a USB 1.1 port, a balloon displays the message "**Your USB device can perform faster if you connect to a USB 2.0 port**." You can ignore this message. The USB-1616FS will function properly when connected to a USB 1.1 port, although USB bandwidth is limited.

After the USB-1616FS is installed the **USB LED** remains lit to indicate that communication is established between the USB-1616FS and your computer.

If the USB LED turns off

If the USB LED is illuminated but then turns off, the computer has lost communication with the USB-1616FS. To restore communication, disconnect the USB cable from the computer, and then reconnect it. This should restore communication, and the USB LED should turn back *on*.

Caution!   Do not disconnect **any** device from the USB bus while the computer is communicating with the USB-1616FS, or you may lose data and/or your ability to communicate with the USB-1616FS.

If your system does not detect the USB-1616FS

If a "**USB device not recognized**" message appears when you connect the USB-1616FS, do the following.

1. Unplug the USB cable from the USB-1616FS.

3. Unplug the external power cord from the **POWER IN** connector on the enclosure.

4. Plug the external power cord back into the **POWER IN** connector.

5. Plug the USB cable back into the USB-1616FS.

Your system should now properly detect the USB-1616FS hardware. Contact technical support if your system still does not detect the USB-1616FS.

Removing USB-1616FS boards from Windows XP systems

Device Manager may require up to 30 seconds to detect the removal of a USB-1616FS board from a Windows XP system with Service Pack 1 or Service Pack 2 installed. This time increases with each additional connected board. If you remove four boards from your system, the time required for Device Manager to update may be almost two minutes.

If you re-attach the USB-1616FS to your system before Device Manager updates, the USB LED will not light. Your system will not detect that new hardware is installed until Device Manager first detects that hardware has been removed.

The *Insta*Cal software will be unresponsive during this re-detection time. Wait until Device Manager updates with the new hardware before running *Insta*Cal. The USB-1616FS has been detected by the system when the USB LED on the USB-1616FS is illuminated.

Functional Details

Theory of operation - analog input acquisition modes

The USB-1616FS can acquire analog input data in three basic modes – software paced, continuous scan, and burst scan.

Software paced mode

You can acquire one analog sample at a time in software paced mode. You initiate the A/D conversion by calling a software command. The analog value is converted to digital data and returned to the computer. You can repeat this procedure until you have the total number of samples that you want from any one channel.

The maximum throughput sample rate in software paced mode is about 250 S/s, but may vary depending on your system.

Continuous scan mode

You can acquire data from up to 16 channels simultaneously in continuous scan mode. The analog data is continuously acquired, converted to digital values, and written to an on-board FIFO buffer on the USB-1616FS until you stop the scan. The FIFO buffer is serviced in blocks as the data is transferred from the USB-1616FS FIFO buffer to the memory buffer on your computer.

You can acquire data with the USB-1616FS from one channel at 50 kS/s and up to 16 channels at 9.5 kS/s each. Table 1 on page 4-2 lists the throughput rates for 1 to 16 channels. You can start a continuous scan with either a software command or with an external hardware trigger event.

Burst scan mode

In burst scan mode, you can acquire data with the USB-1616FS using the full capacity of its 32K sample FIFO. The acquired data is then read from the FIFO and transferred to a user memory buffer on the computer. You can initiate a single acquisition sequence for any number of input channels by either a software command or an external hardware trigger.

Burst scans are limited to the depth of the on-board memory, as the data is acquired at a rate faster than it can be transferred to the computer. The maximum sampling rate is an aggregate rate, where the total acquisition rate for all channels is 200 kS/s divided by the number of channels. The maximum rate for each channel is 50 kS/s. The maximum rate that you can acquire data using burst scan mode is 50 kS/s per channel for one, two, or four channels, and 12.5 kS/s per channel for 16 channels.

Internal components

Major components on the USB-1616FS are shown in Figure 3-1.

- Two (2) USB connectors
- Two (2) external power connectors
- USB LED
- PWR LED
- Four (4) Screw terminal banks
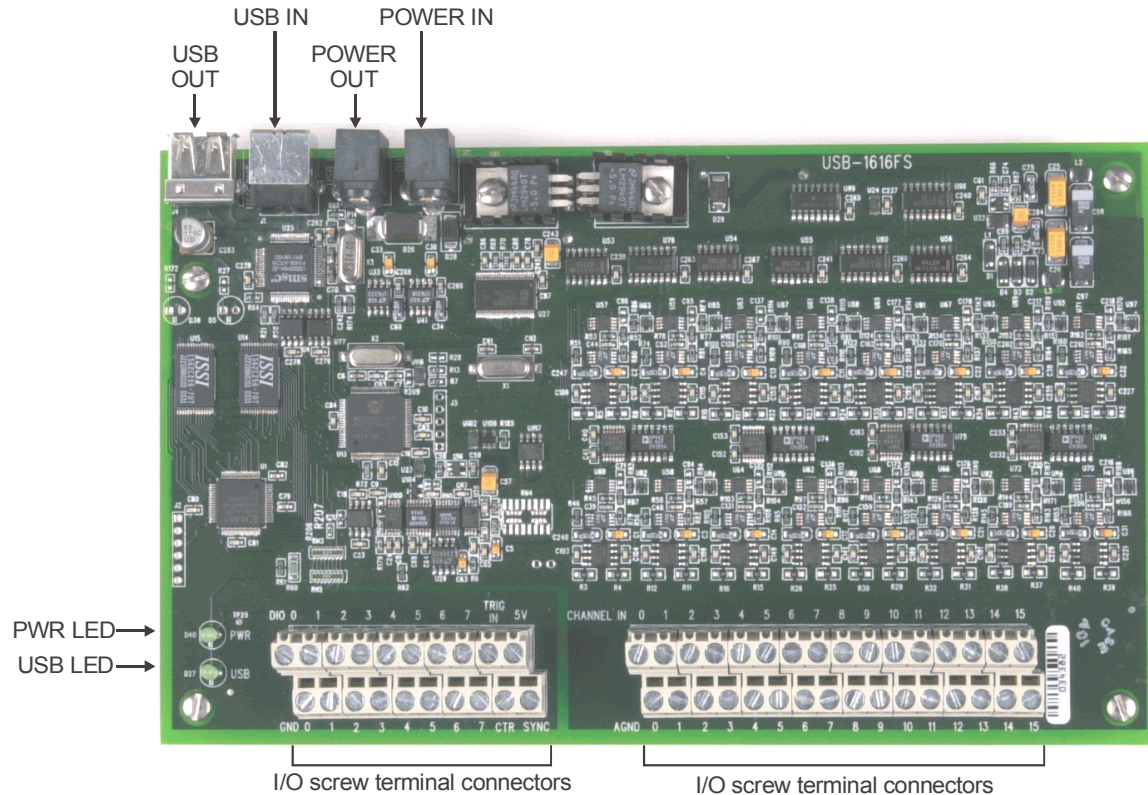
Figure 3-1. USB-1616FS module components

USB OUT connector

The **USB OUT** connector is a downstream hub output port intended for use with other MCC USB Series products only. The USB hub is self-powered, and can provide 100 mA maximum current at 5 V. The USB out connector is labeled **USB OUT** on the enclosure and on the board.

For information on daisy chaining to other MCC USB Series products, refer to Daisy chaining additional modules to the USB-1616FS on page 3-7.

USB IN connector

Connect the **USB IN** connector to the USB port on your computer (or USB hub connected to your computer). The USB in connector is labeled **USB IN** on the enclosure and on the board.

External power connectors

The USB-1616FS has two external power connectors labeled **POWER IN** and **POWER OUT** on the enclosure. The **POWER IN** connector is labeled **IN** on the board, and the **POWER OUT** connector is labeled **OUT** on the board.

To supply external power, connect the **POWER IN** connector to the supplied +9 V external power supply (CB-PWR-9V3A).

The **POWER OUT** connector lets you power additional daisy chained MCC USB Series products from a single external power supply. The C-MAPWR-x cable is available from MCC to connect additional MCC USB Series products.

USB LED

The **USB** LED indicates the communication status of the USB-1616FS. This LED uses up to 5 mA of current and cannot be disabled. Table 3-1 explains the function of the USB LED.

Table 3-1. USB LED Illumination

USB LED illumination	Indication
Steady green	The USB-1616FS is connected to a computer or external USB hub.
Blinks continuously	Initial communication is established between the USB-1616FS and the computer, or data is being transferred.

PWR LED

The USB-1616FS incorporates an on-board voltage supervisory circuit that monitors the USB VBUS (5V) and the external 9 V power supply. If the input voltage falls outside of the specified ranges the **PWR** LED shuts off (see Table 3-2).

Table 3-2. PWR LED Illumination

PWR LED illumination	Indication
Steady green	USB +5 V power or +9 V external power is supplied to the USB-1616FS.
Off	Input power is not supplied, or a power fault has occurred. A power fault occurs when the input power falls outside of the specified voltage range: ▪ USB VBUS (+5 V): 4.75 V to 5.25 V ▪ External power: (+9 V): 6.0 V to 12.5 V

Screw terminal wiring

The USB-1616FS has two rows of screw terminals. Each row has 26 connections. Signal labels are shown in Figure 3-2.
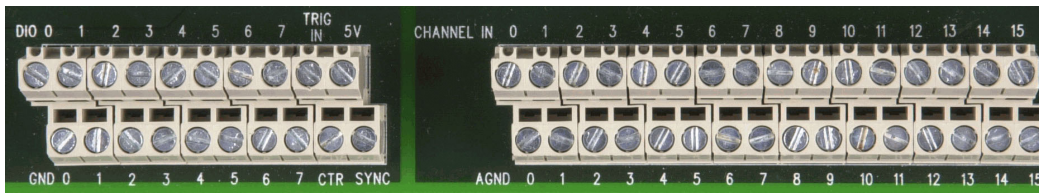
Figure 3-2. USB-1616FS screw terminals

The screw terminals provide the following connections:

- eight digital I/O terminals (**DIO 0** to **DIO 7**)
- one external digital trigger terminal (**TRIG IN**)
- one power terminal (**5V**)
- eight ground terminals (**GND 0** to **7**)
- one external event counter terminal (**CTR**)
- one terminal for external clocking and multi-unit synchronization (**SYNC**)
- 16 analog input terminals (**CHANNEL IN 0 to 15**)
- 16 analog ground terminals (**AGND 0 to 15**)

Use 14 AWG to 30 AWG wire for your signal connections.

> **Caution!**   **Keep the length of stripped wire at a minimum to avoid a short to the enclosure!** When connecting your field wiring to the screw terminals, use the strip gage on the terminal strip, or strip to 5.5 - 7.0 mm (0.215" to 0.275") long.

Each screw terminal is identified with a label on the board and on the underside of the enclosure lid. Refer to Table 3-3 for the signal name associated with each board label.

Table 3-3. Board labels and associated signal names

Board label		Signal name	Board label		Signal name
DIO	0	DIO 0	GND	0	GND 0
	1	DIO 1		1	GND 1
	2	DIO 2		2	GND 2
	3	DIO 3		3	GND 3
	4	DIO 4		4	GND 4
	5	DIO 5		5	GND 5
	6	DIO 6		6	GND 6
	7	DIO 7		7	GND 7
TRIG IN		TRIG IN	CTR		CTR
5V		5V	SYNC		SYNC
CHANNEL IN	0	CH 0	AGND	0	AGND 0
	1	CH 1		1	AGND 1
	2	CH 2		2	AGND 2
	3	CH 3		3	AGND 3
	4	CH 3		4	AGND 4
	5	CH 4		5	AGND 5
	6	CH 5		6	AGND 6
	7	CH 6		7	AGND 7
	8	CH 8		8	AGND 8
	9	CH 9		9	AGND 9
	10	CH 10		10	AGND 10
	11	CH 11		11	AGND 11
	12	CH 12		12	AGND 12
	13	CH 13		13	AGND 13
	14	CH 14		14	AGND 14
	15	CH 15		15	AGND 15

Analog input terminals (CH0 IN to CH15 IN)

You can connect up to 16 analog input connections (**CH0 IN** through **CH15 IN**) to the screw terminals labeled **Channel IN 0-15**. We recommend that you connect unused analog input terminals to ground terminals during operation. For example, if you are not using **CH7 IN**, connect this terminal to **AGND 7**.

Input configuration

All of the analog input channels are configured for single-ended input mode. Each analog signal is referenced to a signal ground (AGND), and requires two wires:

- The wire carrying the signal to be measured connects to CH# IN.
- The second wire connects to AGND.

The input voltage ranges are ±10 V, ±5 V, ±2.0 V, and ±1.0 V. The following image illustrates a typical single-ended measurement connection.
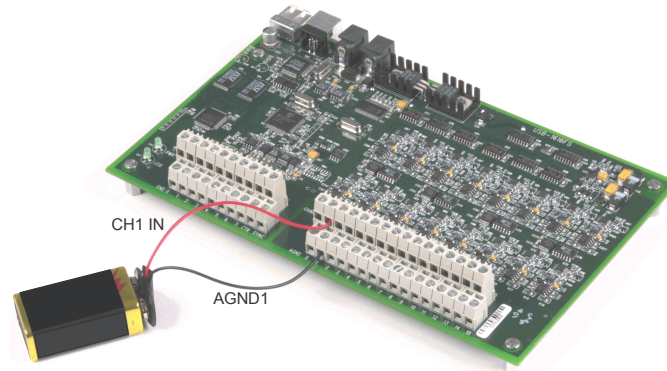
Figure 3-3. Single-Ended measurement connection

The following image shows the single-ended measurement data acquired by TracerDAQ's strip chart.
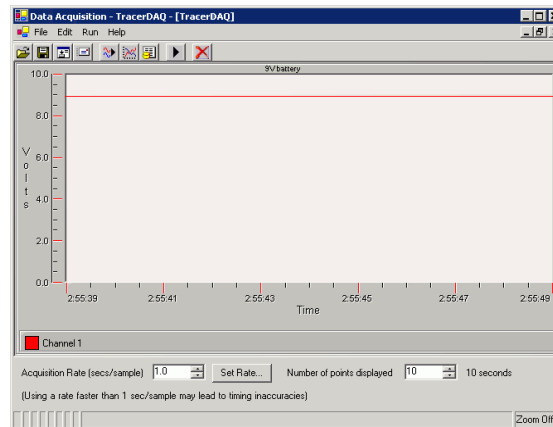
Figure 3-4. TracerDAQ showing single-ended measurement data

For more information on analog signal connections
For more information on single-ended inputs, refer to the *Guide to Signal Connections* (this document is available on our web site at www.mccdaq.com/signals/signals.pdf).

Digital I/O terminals (DIO0 to DIO7)

You can connect up to eight digital I/O lines to the screw terminals labeled **DIO 0** to **DIO 7**. You can configure each digital bit for either input or output. All digital I/O lines are pulled up to USB +5V with a 47 K resistor (default). You can request the factory to configure the resistors for pull-down to ground if desired.

When you configure the digital bits for input, you can use the USB-1616FS digital I/O terminals to detect the state of any TTL-level input. Refer to the switch circuit shown in Figure 3-5 and the schematic shown in Figure 3-6. If you set the switch to the +5V position, DIO4 reads *TRUE* (1). If you move the switch to the GND position, DIO4 reads *FALSE* (0).
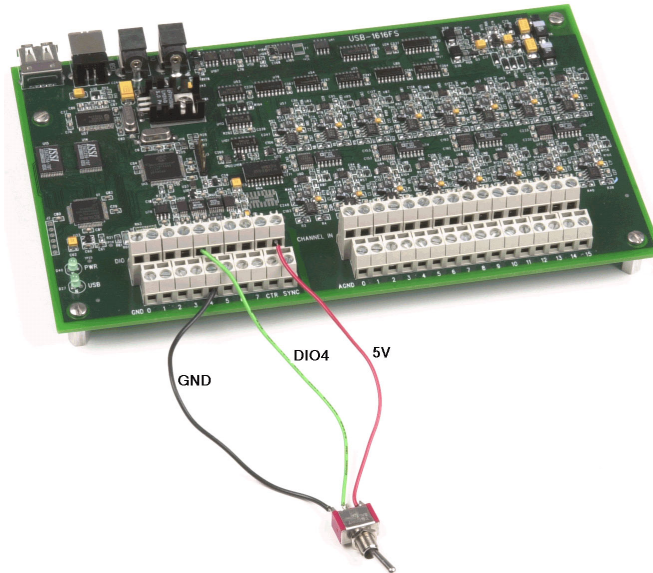
Figure 3-5. Digital connection DIO4 detecting the state of a switch
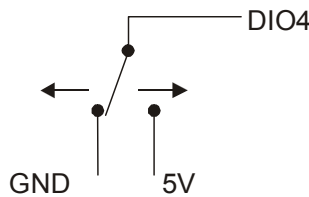
Figure 3-6. Schematic showing switch connection to digital channel DIO4

For more information on digital signal connections

For general information regarding digital signal connections and digital I/O techniques, refer to the *Guide to Signal Connections* (available on our web site at www.mccdaq.com/signals/signals.pdf).

Power terminals

The **+5V** terminal (labeled **5V**) draws power from either the USB connector VBUS terminal or the external power supply.

Caution!   The +5V terminal is an output. Do not connect to an external power supply or you may damage the USB-1616FS and possibly the computer.

The maximum amount of +5 V current from the +5 V terminal is limited to 50 mA.

Ground terminals

The USB-1616FS has 16 analog ground connections (**AGND 0 to 15**) and eight digital ground connections (**GND 0 to 7**). The analog ground connections provide a common ground for the analog input channels. The ground connections provide a common ground for the **DIO 0** to **DIO 7**, **TRIG IN**, **CTR**, **SYNC** and **VDC** connections.

Counter terminal

The CTR terminal (**CTR**) is a TTL level input to a 32-bit event counter. The internal counter increments when the TTL level transitions from low to high. The counter can count frequencies of up to 1 MHz.

Trigger terminal

The trigger terminal (**TRIG IN**) is an external digital trigger input. You can configure this terminal with software for either rising (default) or falling edge.

SYNC terminal

The **SYNC** terminal is a bidirectional I/O signal that you can use for two purposes:

- Configure as an external clock input to externally clock the A/D conversions. The **SYNC** terminal supports TTL-level input signals.
- Configure as an output to synchronize with a second USB-1616FS and acquire data from 32 channels.

Refer to the pinout diagram on page 3-4 for the location of this pin. For more information, refer to "Synchronizing multiple units" on page 3-11.

Daisy chaining additional modules to the USB-1616FS

Daisy chained MCC USB Series products connect to the USB bus through the high-speed hub on the USB-1616FS. You can daisy chain a maximum of four MCC USB Series products to a single USB 2.0 port on your computer, or a maximum of two devices to a single USB 1.1 port. Use the supplied cable or an equivalent cable for daisy chaining to additional MCC USB Series products.

MCC USB Series products are USB 2.0 full-speed devices that provide a signaling bit rate of 12 Mb/s. The throughput rate is shared by all devices connected to the USB bus.

To daisy-chain two or more USB-1616FS modules, follow the steps below. This procedure assumes you already have one USB-1616FS connected to a computer and to the external power source. The USB-1616FS already connected to the computer is referred to as the *connected module*. The USB-1616FS you want to daisy-chain to the connected module is referred to as the *new module*.

1. Connect the **Power OUT** connector on the connected module to the **POWER IN** connector on the new module.

2. Connect the **USB OUT** connector on the connected module to the **USB IN** connector on the new module.

3. For each additional module you want to add, repeat steps 1-2, with the module you just daisy chained now being the *connected module.*

A daisy chain system is shown in Figure 3-7.
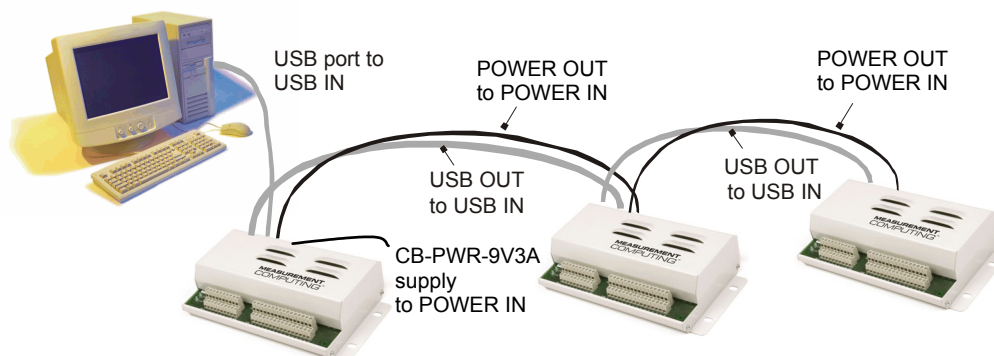
Figure 3-7. USB-1616FS daisy-chain connections

Sample rate limitations when using multiple USB-1616FS devices

The maximum sample rate when using multiple USB-1616FS boards is system-dependent. Multiple board performance is limited by an overall aggregate sample rate. The maximum throughput is in number of samples taken per second. The rate is irrespective of the number of channels sampled or the number of boards installed. The maximum sample rate of any one channel is limited to 50 KS/s.

The typical limiting factor for throughput is CPU usage. At maximum system throughput, virtually all available CPU power is consumed by the USB data transfer. When you run your system close to its maximum throughput, the amount of CPU power that is available for running other concurrent processes is limited. Benchmark performance rates are listed in the *Specifications* chapter on page 4-2.

Power limitations when using multiple USB-1616FS devices

When daisy chaining additional MCC USB Series products to the USB-1616FS, you must ensure that you provide adequate power to each board that you connect. The USB-1616FS is powered with a 9 VDC nominal, 3.0 A external power supply.

Voltage drop

A drop in voltage occurs with each board connected in a daisy chain system. The voltage drop between the power supply input and the daisy chain output is 0.5 V maximum. Factor in this voltage drop when you configure a daisy chain system to ensure that at least 6.0 VDC is provided to the last board in the chain.

Accuracy

The overall accuracy of any instrument is limited by the error components within the system. Quite often, resolution is incorrectly used to quantify the performance of a measurement product. While "16-bits" or "1 part in 65536" does indicate what can be resolved, it provides little insight into the quality, or accuracy, of an absolute measurement. Accuracy specifications describe the actual measurement that can be relied upon with a USB-1616FS.

There are three types of errors which affect the accuracy of a measurement system:

- offset
- gain
- nonlinearity

The primary error sources in the USB-1616FS are offset and gain. Nonlinearity is small in the USB-1616FS, and is not significant as an error source with respect to offset and gain.

Figure 3-8 shows an ideal, error-free, USB-1616FS transfer function. The typical calibrated accuracy of the USB-1616FS is range-dependent, as explained in Chapter 4, "Specifications." We use a ±10V range as an example of what you can expect when performing a measurement in this range.

The accuracy plot in Figure 3-8 is drawn for clarity and is not drawn to scale.
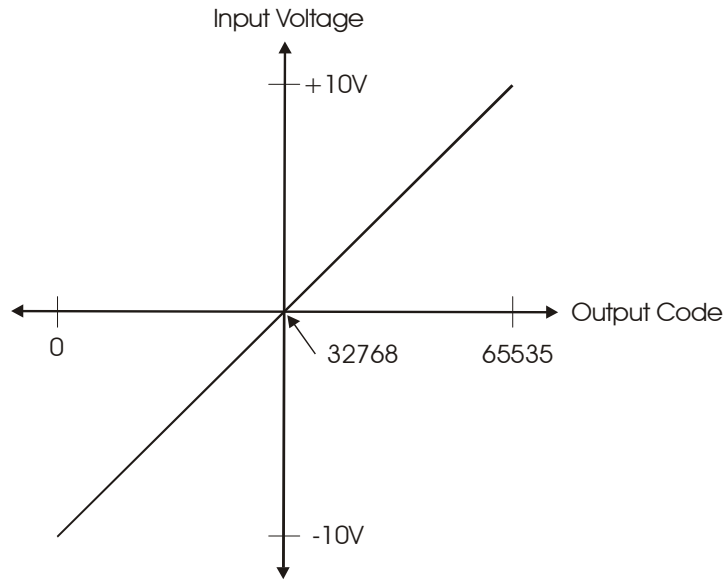
Figure 3-8. Ideal USB-1616FS transfer function

The USB-1616FS offset error is measured at mid-scale. Ideally, a zero volt input should produce an output code of 32768. Any deviation from this is an offset error. Figure 3-9 shows the USB-1616FS transfer function with an offset error. The typical offset error specification for the USB-1616FS on the ±10 V range is ±1.66 mV. Offset error affects all codes equally by shifting the entire transfer function up or down along the input voltage axis.

The accuracy plots in Figure 3-9 are drawn for clarity and are not drawn to scale.
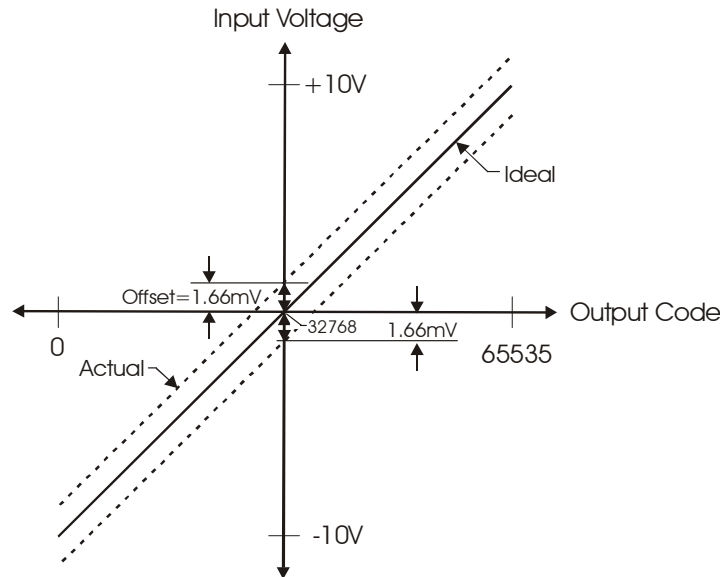
Figure 3-9. USB-1616FS transfer function with offset error

Gain error is a change in the slope of the transfer function from the ideal, and is typically expressed as a percentage of full-scale. Figure 3-10 shows the USB-1616FS transfer function with gain error. Gain error is easily converted to voltage by multiplying the full-scale input (±10 V) by the error.

The accuracy plots in Figure 3-10 are drawn for clarity and are not drawn to scale.
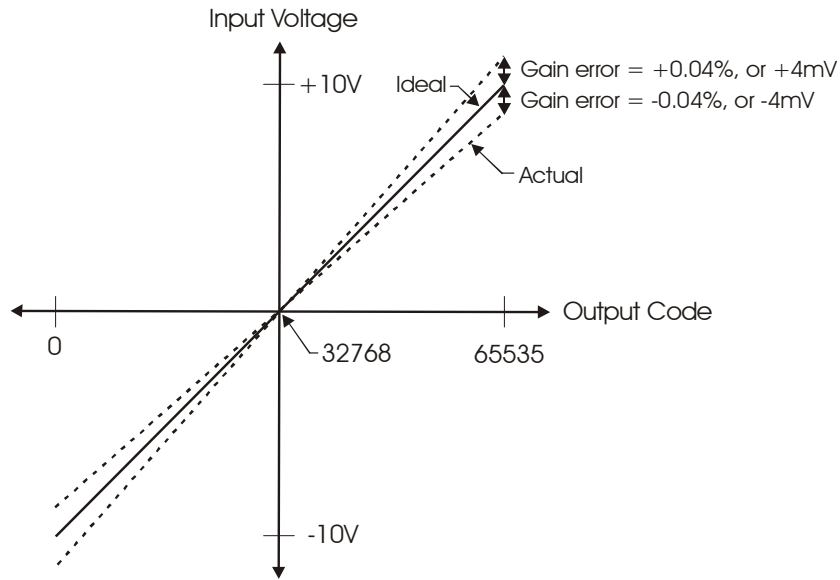
Figure 3-10. USB-1616FS transfer function with gain error

For example, the USB-1616FS exhibits a typical calibrated gain error of ±0.04% on all ranges. For the ±10 V range, this would yield 10 V × ±0.0004 = ±4 mV. This means that at full scale, neglecting the effect of offset for the moment, the measurement would be within 4 mV of the actual value. Note that gain error is expressed as a ratio. Values near ±FS (±10 V) are more affected from an absolute voltage standpoint than are values near mid-scale, which see little or no voltage error.

Combining these two error sources in Figure 3-11, we have a plot of the error band of the USB-1616FS at ±full scale (±10 V). This plot is a graphical version of the typical accuracy specification of the product.

The accuracy plots in Figure 3-11 are drawn for clarity and are not drawn to scale.
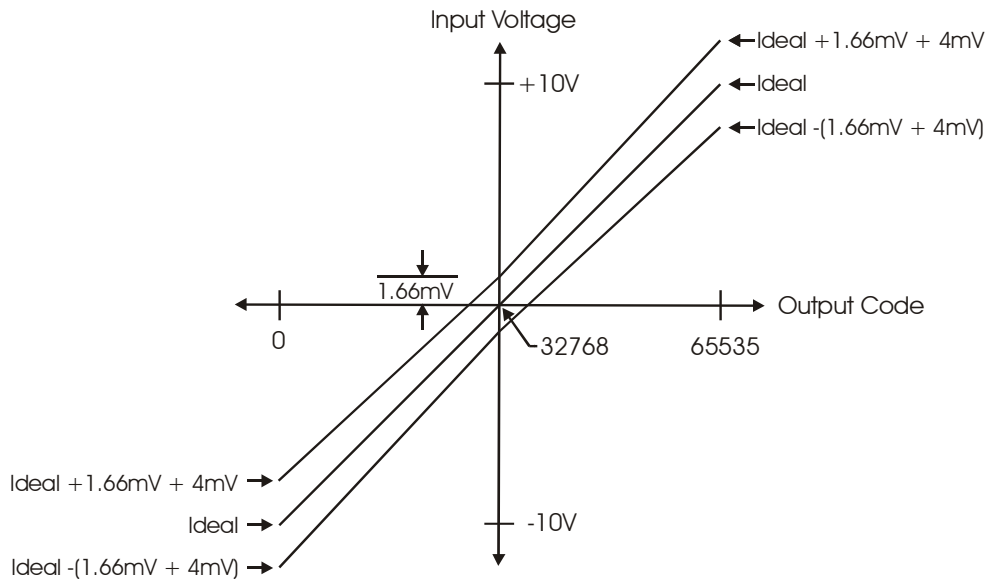
Figure 3-11. USB-1616FS error band plot

Gain queue

The USB-1616FS gain queue allows you to set up a different gain setting for each channel. The gain queue removes the restriction of having a single gain for all channels. This feature creates a gain list which is written to local memory on the USB-1616FS. The gain list is made up of a channel number and range setting. An example of a 16-element list is shown in Table 3-4.

Table 3-4. Sample gain queue list

Element	Channel	Range
0	CH0	BIP10V
1	CH1	BIP5V
2	CH2	BIP10V
3	CH3	BIP1V
4	CH4	BIP2V
5	CH5	BIP10V
6	CH6	BIP1V
7	CH7	BIP5V
8	CH8	BIP2V
9	CH9	BIP1V
10	CH10	BIP2V
11	CH11	BIP5V
12	CH12	BIP10V
13	CH13	BIP2V
14	CH14	BIP1V
15	CH15	BIP10V

Note that the gain queue must contain 16 elements that include all 16 channels. You must carefully match the gain to the expected voltage range on the associated channel ― otherwise, an over range condition can occur. Although this condition does not damage the USB-1616FS, it does produce a useless full-scale reading. It can also introduce a long recovery time due to saturation of the input channel.

Synchronizing multiple units

You can connect the SYNC pin of two USB-1616FS units together in a master/slave configuration and acquire data synchronously from 32 channels. When the SYNC pin is configured as an output, the internal A/D pacer clock signal is present at the screw terminal. You can output the A/D pacer clock to the SYNC pin of a second USB-1616FS configured for A/D pacer input.

You set the function of the SYNC pin (pin 42) for pacer input or pacer output by using *Insta*Cal. By default, the SYNC pin is set for pacer input. To synchronize a master USB-1616FS with a slave USB-1616FS and acquire data from 32 channels, follow the steps below:

1. Run *Insta*Cal.

2. Double-click on the USB-1616FS listing on the **PC Board List** on the **InstaCal** main window. The **Board Configuration** dialog displays.

3. Configure the SYNC pin of the master USB-1616FS for pacer output:

   o Double-click on the USB-1616FS that you want to configure as the master. The **Board Configuration** dialog displays.

   o Click to select the **Enable Sync output** check box and then click **OK**.

4. Configure the SYNC pin of the slave USB-1616FS for pacer input:

    o Double-click on the USB-1616FS that you want to configure as the slave. The **Board Configuration** dialog displays.

    o Make sure that the **Enable Sync output** check box is not checked (unchecked is the default setting).

    <p style="text-align:center">☐ Enable SYNC output</p>

5. Connect the SYNC pin of the master USB-1616FS to the SYNC pin of the slave USB-1616FS.

6. Set the Universal Library `EXTCLOCK` option with `cbAInScan()`/`AInScan` for the slave USB-1616FS to enable external pacer clock input.

An example of a master/slave configuration is shown below.
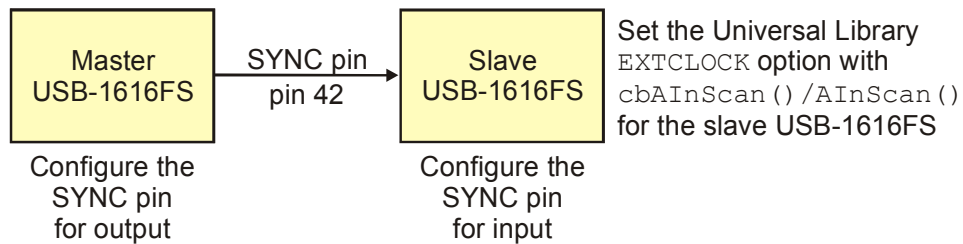
Figure 3-12. Configuring for synchronous data acquisition

When you are operating one USB-1616FS, do not set the `EXTCLOCK` option unless you are using an external clock for A/D pacing.

Specifications

Typical for 25 °C unless otherwise specified.

Specifications in *italic text* are guaranteed by design.

Analog input

Parameter	Conditions	Specification
A/D converters		16-bit, SAR type
Number of channels		16 single-ended
Input configuration		Individual A/D per channel
Sampling method		Simultaneous
Absolute maximum input voltage	*CHx IN to GND*	*±15 V max.*
Input impedance		100 MOhm, min.
Input bandwidth (-3 dB)		50 kHz typ.
Input leakage current		±1 µA typ.
Input capacitance		*50 pf typ.*
Offset temperature drift		15 ppm/°C typ.
Gain temperature drift	All ranges	35 ppm/°C typ.
Input ranges	Software selectable	±10 V, ±5 V, ±2 V, ±1 V
Sampling rate	Scan to PC memory	0.6 S/s to 50 kS/s, software programmable
	Burst scan to 32 k sample FIFO	20 S/s to 50 kS/s, software programmable
Throughput	Software paced	30 – 500 S/s all channels (throughput is system dependant)
	Scan to PC memory	Refer to the Single Board Throughput and Multiple Board Throughput sections that follow this table.
	Burst scan to 32 k Sample FIFO	= (200 kS/s) / (# of channels), max of 50 kS/s for any channel
Gain queue		Software configurable. Sixteen elements, one gain element per channel.
Resolution		16 bits
No missing codes		*15 bits*
Crosstalk	Dc – 25 kHz (sine)	-80 dB min.
Calibration voltages		0 V, ±0.625 V, ±1.25 V, ±2.5 V, ±5.0 V, software selectable
Calibration voltage accuracy (Note 1)		±0.5% typ., ±1.0% max.
Temperature sensor range		0 °C to +70 °C max.
Temperature sensor accuracy		±3 °C typ.
Trigger source	Software selectable	External digital: TRIG_IN

Note 1: Actual values used for calibration are measured and stored in EEPROM.

Single board throughput

The USB-1616FS has an integral USB hub, which allows up to four USB-1616FS boards to be daisy chained and connected to a single USB 2.0 port on the host computer. The data shown in Table 1 reflects the throughput that can be expected in single board systems. For details on throughput in systems using multiple USB-1616FS boards, please refer to the next section "Multiple board throughput."

Table 1. Single board throughput: Scan to PC memory

Number of Input Channels	Per-channel Throughput (kS/s) (Note 2)
1	50000
2	50000
3	36000
4	30000
5	25000
6	22000
7	19000
8	17000
9	15000
10	14000
11	12500
12	12000
13	11250
14	10500
15	10000
16	9500

Note 2:   The throughput data in Table 1 applies to a single USB-1616FS device installation only. Maximum throughput scanning to PC memory is highly machine dependent.

The rates specified in Table 1 is for Windows XP only. The maximum throughput rates on operating systems that predate Windows XP may be less and must be determined through testing on your machine.

Multiple board throughput

The USB-1616FS has an integral USB hub, which allows up to four USB-1616FS boards to be daisy chained and connected to a single USB 2.0 port on the host computer. (The data shown in Table 1 reflects the throughput that can be expected in single board systems.) The transfer of USB-1616FS data over the USB bus is very CPU intensive. The transfer rate using multiple USB-1616FS boards is both CPU intensive and system dependent. This makes it impossible for us to provide a guaranteed spec for multi-board maximum sample rate. However, the benchmark performance shown below should serve as a guide for what you may expect.

Multiple board performance is limited by an overall aggregate sample rate. The maximum throughput will be in number of samples taken per second irrespective of the number of channels sampled* or number of boards installed. For example, if the maximum throughput in a system is 150,000 samples per second, you may sample 20 channels at 7.5 kS/s, 30 channels at 5 kS/s, 40 channels at 3.75 kS/s, etc.

*the maximum sample rate of any one channel is limited to 50 KS/s.

Throughput benchmarks

Throughput	System
240 kS/s	2.4 GHz P4 running Win XP, Service Pack 2, using an integrated USB Enhanced Host Controller (EHC) port
240 kS/s	2.4 GHz P4, Phoenix BIOS, Win XP, Service Pack 2, integrated USB EHC port
130 kS/s	2 GHz, Xeon, Win XP, Service Pack 2, hyperthreading turned OFF, using an integrated USB EHC port
220 kS/s	2 GHz, Xeon, Win XP, Service Pack 2, hyperthreading turned ON, using an integrated USB EHC port
260 kS/s	2.4 GHz, P4 running Win XP, Service Pack 1, using Belkin PCI-bus USB 2.0 card
250 kS/s	2.4 GHz, P4 running Win XP, Service Pack 1, using StarTec PCI-bus USB 2.0 card

Usage note

The typical limiting factor on throughput is CPU usage. At maximum system throughput, virtually all available CPU power will be consumed by the USB data transfer. This is an important note since running your system close to its maximum throughput will certainly limit the amount of CPU power available for running other concurrent processes (for example, plotting or real-time analysis).

Table 2. Calibrated absolute accuracy

Range	Accuracy (mV)
±10 V	±5.66
±5 V	±2.98
±2 V	±1.31
±1 V	±0.68

Table 3. Accuracy components - all values are (±)

Range	% of Reading	Gain Error at FS (mV)	Offset (mV)
±10 V	0.04	4.00	1.66
±5 V	0.04	2.00	0.98
±2 V	0.04	0.80	0.51
±1 V	0.04	0.40	0.28

Table 4. Noise performance

Range	Typical Counts	LSBrms
±10 V	10	1.52
±5 V	10	1.52
±2 V	11	1.67
±1 V	14	2.12

Noise distribution is determined by gathering 50 k samples with analog inputs tied to ground (AGND) at the user connector. Samples are gathered at the maximum specified sampling rate of 50 kS/s.

Digital input/output

Digital type	CMOS
Number of I/O	8 (DIO0 through DIO7)
Configuration	Independently configured for input or output
Pull up/pull-down configuration	All pins pulled up to USB VBUS via 47 K resistors (default). Positions available for pull down to ground (GND). Hardware selectable via zero ohm resistors as a factory option.
Digital I/O transfer rate (software paced)	System dependent, 33 to 1000 port reads/writes or single bit reads/writes per second typ.
Input high voltage	2.0 V min., 5.5 V absolute max.
Input low voltage	0.8 V max., -0.5 V absolute min.
Output high voltage (IOH = -2.5 mA)	3.8 V min.
Output low voltage (IOL = 2.5 mA)	0.7 V max.
Power on and reset state	Input

External trigger

Parameter	Conditions	Specification
Trigger source (Note 3)	External digital	TRIG_IN
Trigger mode	Software selectable	Edge Sensitive: user configurable for CMOS compatible rising (default) or falling edge.
Trigger latency		10 µs max.
Trigger pulse width		1 µs min
Input high voltage		4.0 V min, 5.5 V absolute max.
Input low voltage		1.0 V max,-0.5 V min
Input leakage current		*±1.0µA*

Note 3:   TRIG_IN is a Schmitt trigger input protected with a 1.5 k Ohm series resistor.

External clock input/output

Parameter	Conditions	Specification
Pin name		SYNC
Pin type		Bidirectional
Software selectable direction	Output	Outputs internal A/D pacer clock.
	Input	Receives A/D pacer clock from external source. Rising edge sensitive.
Input clock rate		50 kHz, maximum
Clock pulse width	Input	1 µs min.
	Output	5 µs min.
Input leakage current		*±1.0 µA*
Input high voltage		4.0 V min., 5.5 V absolute max.
Input low voltage		1.0 V max., -0.5 V absolute min.
Output high voltage (Note 4)	IOH = -2.5 mA	3.3 V min.
	No load	3.8 V min.
Output low voltage (Note 4)	IOL = 2.5 mA	1.1 V max.
	No load	0.6 V max.

Note 4:   SYNC is a Schmitt trigger input and is over-current protected with a 200 Ohm series resistor.

Counter

Pin name	CTR
Counter type	Event counter
Number of channels	1
Input type	TTL, rising edge triggered
Resolution	32 bits
Counter/timer read/write rates (software paced)	Counter Read – System dependent, 33 to 1000 reads per second.
	Counter Clear – System-dependent, 33 to 1000 writes per second.
Schmidt trigger hysteresis	*20 mV to 100 mV*
Input leakage current	*± 1 µA*
Maximum input frequency	1 MHz
High pulse width	*500 ns min.*
Low pulse width	*500 ns min.*
Input low voltage	1.0 V min., -0.5 V max.
Input high voltage	4.0 V min., 5.5 V max.

Memory

Data FIFO	32,768 samples, 65,536 bytes		
EEPROM	1,024 bytes		
EEPROM configuration	**Address range**	**Access**	**Description**
	0x000-0x07F	Reserved	128 bytes system data
	0x080-0x1FF	Read/Write	384 bytes calibration data
	0x200-0x3FF	Read/Write	512 bytes user area

Microcontroller

Type	High performance 8-bit RISC microcontroller
Program memory	16,384 words
Data memory	2,048 bytes

Power

Parameter	**Conditions**	**Specification**
Supply current	USB enumeration	<100 mA
Supply current (Note 5)	Continuous mode	350 mA typ.
User +5 V output voltage range (Note 6)	Available at terminal block pin 48	4.0 V min. 5.25 V max.
User +5V output current (Note 7)	Available at terminal block pin 48	50 mA max.

Note 5: This is the total current requirement for the USB-1616FS which includes up to 10mA for the status LED's.

Note 6: Output voltage range assumes input power supply voltage is within specified limits

Note 7: This refers to the total amount of current that can be sourced from the 5 V screw terminal (pin 48) for general use. This spec includes any additional contribution due to DIO loading.

USB +5 V voltage

Parameter	**Conditions**	**Specification**
USB +5V (VBUS) input voltage range.		4.75 V min. to 5.25 V max.

External power input

Parameter	Conditions	Specification
External power input		+6.0 VDC to 12.5 VDC (9 VDC power supply included).
Voltage supervisor limits - PWR LED. (Note 8)	6.0 V > Vext or Vext > 12.5 V	PWR LED = Off (power fault)
	6.0 V < Vext < 12.5 V	PWR LED = On
External power adapter (included)	MCC p/n CB-PWR-9V3A	+9 V ±10%, @ 3 A

Note 8: The USB-1616FS monitors the external +9 V power supply voltage with a voltage supervisory circuit. If this power supply exceeds its specified limit, the PWR LED will turn off indicating a power fault condition.

External power output

Parameter	Conditions	Specification
External power output - current range	Note 9	4.0 A max.
External power output	Voltage drop between power input and daisy chain power output	0.5 V max
Compatible cable(s) for daisy chain	C-MAPWR-x	X = 2, 3 or 6 feet

Note 9: The daisy chain power output option allows multiple MCC USB Series products to be powered from a single external power source in a daisy chain fashion. The voltage drop between the module power supply input and the daisy chain output is 0.5 V max. Users must plan for this drop to assure the last module in the chain will receive at least 6.0 VDC

USB specifications

USB "B" connector	Input
USB device type	USB 2.0 (full-speed) *Use of multiple USB-1616FS boards requires a USB 2.0 hub.*
Device compatibility	USB 1.1, USB 2.0
USB "A" connector	Downstream hub output port
USB hub type	Supports USB 2.0 high-speed, full-speed and low-speed operating points.
	Self-powered, 100 mA max downstream VBUS capability
Compatible products	MCC USB Series devices
USB cable type (upstream and downstream)	*A-B cable, UL type AWM 2527 or equivalent. (min 24 AWG VBUS/GND, min 28 AWG D+/D-)*
USB cable length	3 meters max.

Environmental

Operating temperature range	0 to 70 ° C
Storage temperature range	-40 to 85 ° C
Humidity	0 to 90% non-condensing

Mechanical

Card dimensions	203.2 mm (L) x 121.9 mm (W) x 20.0 mm (H)
	8.0" (L) x 4.8" (W) x 0.8" (H)
Enclosure dimensions	241.3 mm (L) x 125.7 mm (W) x 58.9 mm (H)
	9.50" (L) x 4.95" (W)x 2.32" (H)

Screw terminal connector

Connector type	Screw terminal
Wire gauge range	14 AWG to 30 AWG

Connector pin out

Board label		Signal name	Board label		Signal name
DIO	0	DIO 0	GND	0	GND 0
	1	DIO 1		1	GND 1
	2	DIO 2		2	GND 2
	3	DIO 3		3	GND 3
	4	DIO 4		4	GND 4
	5	DIO 5		5	GND 5
	6	DIO 6		6	GND 6
	7	DIO 7		7	GND 7
TRIG IN		TRIG IN	CTR		CTR
5V		5V	SYNC		SYNC
CHANNEL IN	0	CH 0	AGND	0	AGND 0
	1	CH 1		1	AGND 1
	2	CH 2		2	AGND 2
	3	CH 3		3	AGND 3
	4	CH 3		4	AGND 4
	5	CH 4		5	AGND 5
	6	CH 5		6	AGND 6
	7	CH 6		7	AGND 7
	8	CH 8		8	AGND 8
	9	CH 9		9	AGND 9
	10	CH 10		10	AGND 10
	11	CH 11		11	AGND 11
	12	CH 12		12	AGND 12
	13	CH 13		13	AGND 13
	14	CH 14		14	AGND 14
	15	CH 15		15	AGND 15

CE Declaration of Conformity

Manufacturer: Measurement Computing Corporation
Address: 10 Commerce Way
                      Suite 1008
                      Norton, MA 02766
                      USA

Measurement Computing Corporation declares under sole responsibility that the product

USB-1616FS

to which this declaration relates is in conformity with the relevant provisions of the following standards or other documents:

EU EMC Directive 89/336/EEC: Electromagnetic Compatibility, EN 61326 (1997) Amendment 1 (1998)

Emissions: Group 1, Class A

- EN 55011 (1990)/CISPR 11: Radiated and Conducted emissions.

Immunity: EN61326, Annex A

- IEC 1000-4-2 (1995): Electrostatic Discharge immunity, Criteria C.
- IEC 1000-4-3 (1995): Radiated Electromagnetic Field immunity Criteria C.
- IEC 1000-4-4 (1995): Electric Fast Transient Burst immunity Criteria A.
- IEC 1000-4-5 (1995): Surge immunity Criteria C.
- IEC 1000-4-6 (1996): Radio Frequency Common Mode immunity Criteria A.
- IEC 1000-4-8 (1994): Magnetic Field immunity Criteria A.
- IEC 1000-4-11 (1994): Voltage Dip and Interrupt immunity Criteria A.

Declaration of Conformity based on tests conducted by Chomerics Test Services, Woburn, MA 01801, USA in February, 2005. Test records are outlined in Chomerics Test Report #EMI4133.05.

We hereby declare that the equipment specified conforms to the above Directives and Standards.

Carl Haapaoja, Director of Quality Assurance