KUSB Series DAQ Adapter for MATLAB®

User's Guide

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KEITHLEY

A GREATER MEASURE OF CONFIDENCE

DAQ ADAPTER FOR MATLAB®
User's Manual

KEITHLEY Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a ⏚ screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The ⚠ symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The ⚠ symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The ⏚ symbol indicates a connection terminal to the equipment frame.

The WARNING heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The CAUTION heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Overview

This document describes how to install and use the Keithley Instruments KUSB DAQ Adaptor for MATLAB®.

Keithley Instruments KUSB DAQ Adaptor for MATLAB provides an interface between the MATLAB Data Acquisition (DAQ) subsystem from The MathWorks and Keithley Instruments-Open Layers architecture for its KUSB-3100 Series.

Open Layers provides an API to Keithley's KUSB-3100 Series USB data acquisition hardware modules. You can use these two components together to control Keithley Instruments modules with MATLAB and move data directly into MATLAB for analysis and display.

Using these components together, you can create Open Layers subsystems, add channels to them, and perform single-value or streaming I/O through them to MATLAB. MATLAB provides extensive analysis and display features to process the input data and generate output data.

Data Flow Model

The figure below summarizes the relationship between the MATLAB and Keithley Instruments components in a combined configuration:

Control	MATLAB®	Data Flow
	MATLAB® Data Acquisition Toolkit	
	Keithley Instruments DAQ Adapter for MATLAB	
	Open Layers API	
	Keithley Instruments Drivers and Modules	
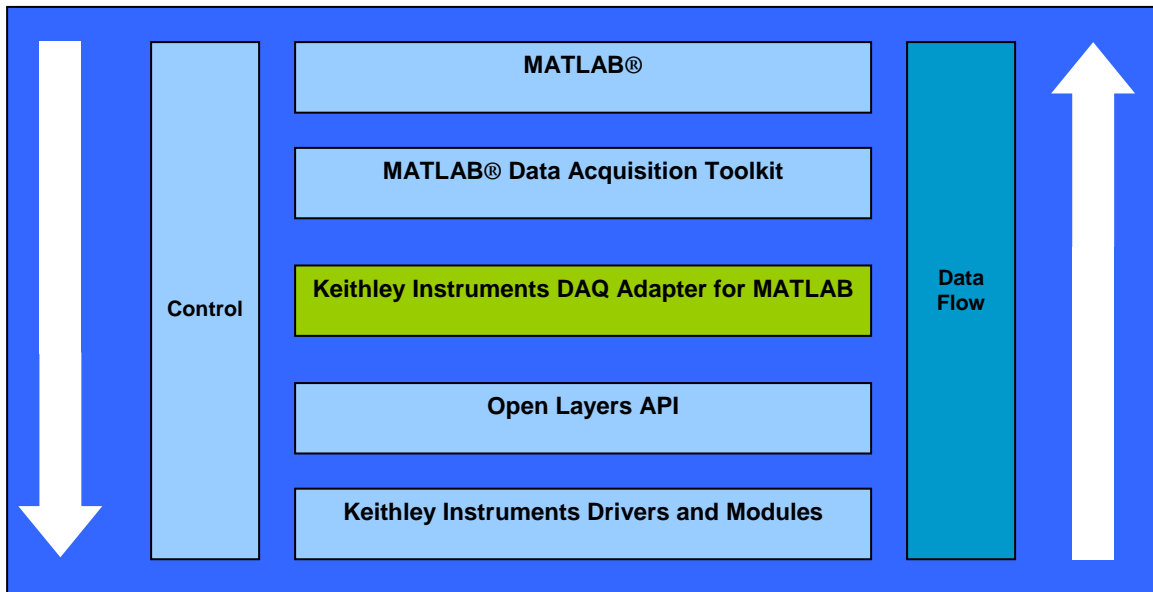
Requirements

You must install the following before you install the Keithley Instruments DAQ Adaptor for MATLAB:

- Your Keithley Instruments hardware module(s) and their drivers (from the KUSB Data Acquisition CD that ships with your hardware)
- Open Layers Version 3.0 or higher
- MATLAB Version 7 (R14) Service Pack 3 or higher
- MATLAB Data Acquisition Toolbox Version 2.7 or higher

Install Keithley Instruments components from a recent KUSB Data Acquisition CD, or download from our web site (www.keithley.com). Contact 'The MathWorks' for updates to your MATLAB components.

Installation

To install the DAQ Adaptor for MATLAB, do the following:
1. Click the link for the adaptor on Keithley Instruments' web site.
2. Choose Open from the Windows dialog box, or choose Save to download the file before proceeding. If you chose the save the file, double-click setup.exe after you download it.
3. Close other programs if necessary, and click Next on the welcome screen.
4. Either change the directory path using Browse or accept the default directory, and then click Next.
   The installer asks you whether to back up replaced files.
5. Choose the Yes or No radio button, and then click Next.
   The installer prompts you to begin file installation.
6. Click Next.
   The installer copies the files to the destination directory.

   After the installer copies the files, it launches MATLAB. MATLAB registers the DAQ Adaptor .DLL using the path you provided:

   ```
   >>rehash toolboxcache;daqregister
   'C:\PROGR~1\KEITHL~1\DAQADA~1\dtol.dll';quit


   >>
   ```
7. When you return to the installer, click Finish.

Using the DAQ Adaptor for MATLAB

The Keithley Instruments DAQ Adaptor for MATLAB is specified as dtol in MATLAB code. The following code example shows a typical operation to create an analog input object (ai0) with the adaptor for a board with index 0, add hardware channel 0 to the object, and get a single sample from that channel:

```
>> ai0 = analoginput ('dtol', 0)
>> addchannel(ai0, 0)
>> s = getsample(ai0)
```

You can display the properties of the adaptor (including installed hardware modules) with the daqhwinfo command:

```
>> daqhwinfo('dtol')
```

If there are too many modules to display on a single line, you can assign daqhwinfo to an array and query the board names separately:

```
>> x = daqhwinfo('dtol')
>> x.BoardNames
```

You can examine properties of a subsystem that you created with the adaptor by using the MATLAB daqhwinfo command (for built-in properties) and get command (for user-settable properties). For example:

```
>> daqhwinfo(ai0)
>> get(ai0)
```

The output includes a list of "DTOL specific properties." You can find out more information about a property using the MATLAB propinfo command:

```
>> propinfo(ai0.channel(1),'gainperchan')
```

To control a data acquisition session, issue MATLAB commands and set properties. For example, to set a "DTOL specific" channel property (or any other channel property), issue a command such as the following:

>> ai0.channel(1).GainPerChan = 4

For more information about using MATLAB commands and MATLAB Data Acquisition Toolbox properties, refer to your MATLAB documentation.

Analog Input and Output

The following adaptor-specific properties are created by the Keithley Instruments DAQ Adaptor for MATLAB for analog operations:

Table 1: Adaptor-Specific Analog Input/Output Properties

Property	Description	A/D	D/a
FIFOAvailable	Determine if a FIFO is available on the subsystem.	No	Yes
FIFODepth	Determine size of the FIFO.	No	Yes
OutOfDataMode	Specify how to handle an out-of-data condition. Set Hold to use the last value in the output buffer. Set Default to use the channel-specific Default Value property.	No	Yes
SupportBinaryEncoding	Determine if subsystem uses binary encoding.	Yes	Yes
SupportExternalTriggerFalling	Check for external, falling-edge triggering support.	Yes	Yes
SupportExternalTriggerRising	Check for external, rising-edge triggering support.	Yes	Yes
SupportGainPerChannel	Determine if subsystem supports different gain values for each analog channel.	Yes	Yes
SupportSoftTrigger	Determine if subsystem supports an internal software trigger.	Yes	Yes
SupportTwosComp	Determine if subsystem uses twos complement encoding.	Yes	Yes

About Input Types

To switch between the differential and single-ended input, use the following command:

>> ai0.inputtype='differential'

You can then use a get(ai0) call to see the changes. When you change input types, the channel lists will change.

About Gain

The following property appears at the channel level after you add a channel:

Table 2: Adaptor-Specific Channel Property

Property	Description	A/D	D/a
GainPerChan	Specify the gain value for a particular analog input channel.	Yes	No

Open Layers uses a per-channel gain concept, which differs from MATLAB's range based per channel setting to control gain and range. You can specify a per-channel gain, or the adaptor attempts to set the best per-channel gain for a specified range.

We recommend using the GainPerChan property for per-channel gain control.

MATLAB Property Notes

The following adaptor-specific notes apply to MATLAB properties:

Table 3: Adaptor Notes for MATLAB Properties

MATLAB Property	Notes
BufferingConfig	The minimum buffer size is 128, but for best performance, set to 1024 or greater. NOTE: If the value for RepeatOutput is greater than 1, the buffer size must be an integer multiple of the number of samples queued. The adaptor warns you of this when you change RepeatOutput.
TotalChannels	This may include channels that are in two lists and have a mode (single-ended vs. differential). Also, when the InputType is changed from SingleEnded to Differential, the channel IDs will change in the DaqHwInfo() listing.
TriggerCondition	Either "RisingEdge" or "FallingEdge" depending upon what the module supports.

Multiple Subsystems of a Single Type

To provide access to all elements of a board with multiple subsystems of a particular type (for example, multiple analog input subsystems, such as on the KUSB-3116), the adaptor creates *virtual boards*. The first board enumerated includes any other types of subsystems.

For example, the KUSB-3116 module enumerates in the adaptor like this:

'KUSB-3116(01)'	A/D, D/A, Digital I/O
'KUSB-3116(01)-1'	A/D
'KUSB-3116(01)-2'	A/D
'KUSB-3116(01)-3'	A/D

To access the fourth A/D subsystem, use the virtual board 'KUSB-3116(01)-3' and its one analoginput() object.

Analog Out Operation Notes

The following caveats apply to analog out operations:

- The number of samples output will not always be correct, particularly when the samples to output are not the same as the buffer size. This is because Open Layers sends the whole buffer to the D/A converter, and the adaptor pads the output buffer to either the Hold value or the channel default value (see "OutOfDataMode").

- Open Layers does not send a message when the actual hardware trigger occurs. Therefore, the time and sample count for the trigger event will not be correct for TriggerType='HwDigital' for analog out.

- The final voltage on a D/A output might be unpredictable after a streaming operation.

Using Hardware Triggers

To use a hardware trigger for analog out, set the TriggerType to 'HwDigital' and set the TriggerCondition property to Rising or Falling.

When the analog output subsystem is started, data buffers may be sent to the hardware FIFO, resulting in a "buffer done" message to the adaptor and a trigger event before the D/A output value has been set. Therefore it may appear that data output occurs before the hardware trigger happens, but the data has only been moved to the board FIFO, not output through the D/A converter.

Known Issues

When the MATLAB TriggerType property is set to Manual, the Start command should prepare the subsystem and await the Trigger command. On the D/A subsystem (analog output), the Start command calls the Trigger command immediately after doing the start in Manual mode, thus behaving exactly like the TriggerType='Immediate' case. This behavior is being investigated and will be fixed in a future release.

Related Information

Refer to the following documents from Keithley Instruments for more information on using Open Layers:

- *DataAcq SDK User's Manual* (DASK-900-01 Rev. A or higher). For programmers who are developing their own application programs using the Microsoft C compiler, this manual describes how to use the Open Layers^{TM} DataAcq SDK^{TM} to access the capabilities of Keithley Instruments data acquisition devices.
- *DTx-EZ Getting Started Manual* (DTXEZ-903-01 Rev. A or higher). This manual describes how to use the ActiveX controls provided in DTx-EZ^{TM} to access the capabilities of Keithley Instruments data acquisition devices in Microsoft Visual Basic® or Visual C++®.