KUSB-3100

User's Manual

KUSB3100-900-01 Rev. A / January 2005

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Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 3 years from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

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This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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12/04

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First Printing, January 2005
Cleveland, Ohio, U.S.A.
Document Number: KUSB3100-900-01 Rev. A

Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number KUSB3100-900-01A)..... January 2005

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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.

Table of Contents

About this Manual

This manual describes the features of the KUSB-3100 module, the capabilities of the device driver, and how to program this module using DT-Open Layers™ software. Troubleshooting information is also provided.

Intended Audience

This document is intended for engineers, scientists, technicians, or others responsible for using and/or programming the KUSB-3100 module for data acquisition operations in Microsoft® Windows 2000 or Windows XP. It is assumed that you have some familiarity with data acquisition principles and that you understand your application.

What You Should Learn from this Manual

This manual provides detailed information about the features of the KUSB-3100 module and the capabilities of the device driver. The manual is organized as follows:

- Chapter 1, "Overview," describes the major features of the KUSB-3100 module, as well as the supported software for the module.
- Chapter 2, "Principles of Operation," describes all of the features of the module and how to use them in your application.
- Chapter 3, "Supported Device Driver Capabilities," lists the data acquisition subsystems and the associated features accessible using the device driver.

- Chapter 4, "Programming Flowcharts," describes the processes you must follow to program the subsystems on the KUSB-3100 module using DT-Open Layers-compliant software.
- Chapter 5, "Troubleshooting," provides information that you can use to resolve problems with the module and the device driver, should they occur.
- Chapter 6, "Calibration," describes how to calibrate the analog I/O circuitry of the KUSB-3100 module.
- Appendix A, "Specifications," lists the specifications of the module.
- Appendix B, "Connector Pin Assignments," shows the screw terminal assignments for the module.
- Appendix C, "Reading from or Writing to the Digital Registers," describes register-level functions you can use to program the digital I/O lines of the module.
- An index completes this manual.

Conventions Used in this Manual

The following conventions are used in this manual:

- Notes provide useful information or information that requires special emphasis, cautions provide information to help you avoid losing data or damaging your equipment, and warnings provide information to help you avoid catastrophic damage to yourself or your equipment.
- Items that you select or type are shown in **bold**.

Related Information

Refer to the following documents for more information on using the KUSB-3100 module:

- *KUSB-3100 Getting Started Manual* provided with the module. This manual describes how to install and wire signals to the KUSB-3100 module.
- *DataAcq SDK User's Manual*. For programmers who are developing their own application programs using the Microsoft C compiler, this manual describes how to use the DT-Open Layers™ DataAcq SDK™ in Windows 2000 or Windows XP to access the capabilities of your module.
- *DTx-EZ Getting Started Manual*. This manual describes how to use the ActiveX controls provided in DTx-EZ™ to access the capabilities of your module in Microsoft Visual Basic® or Visual C++®.
- *DT-LV Link Getting Started Manual.* This manual describes how to use DT-LV Link™ with the LabVIEW® graphical programming language to access the capabilities of your module.
- Microsoft Windows 2000 or Windows XP documentation.
- USB web site (http://www.usb.org).
- *Omega Complete Temperature Measurement Handbook and Encyclopedia®.* This document, published by Omega Engineering, provides information on how to linearize voltage values into temperature readings for various thermocouple types.

Where To Get Help

Should you run into problems installing or using your KUSB-3100 module, please call the Keithley Technical Support Department.

Overview

Features

The KUSB-3100 module is an economy, multifunction mini-instrument. Table 1 lists the key features of the module.

Table 1: Key Features of the KUSB-3100 Module

Analog Inputs	Analog Outputs	Resolution	I/O Range	Sample Rate	Digital I/O	Counter/ Timer[a]
8 SE	2	12-bit	±10 V	50 kS/s	8 in, 8 out	1

a. This counter/timer channel allows you to perform event counting, frequency measurement, edge-to-edge measurement, and continuous pulse output (rate generation) operations.

In addition, the KUSB-3100 module provides these features:

- 16-location channel-gain list. You can cycle through the channel-gain list using continuous scan mode or triggered scan mode.
- 2-location output channel list. You can update both analog output channels simultaneously at up to 50 kSamples/s.
- 8 fixed digital input lines and 8 fixed digital output lines.
- One 32-bit counter/timer (C/T) channel that performs event counting, frequency measurement, edge-to-edge measurement, and rate generation operations (the resolution of the C/T is 16-bits in this mode).
- Internal and external A/D clock sources.
- Internal and external A/D trigger sources.
- No external power supply required. These are low-power required (less than 100 mA draw).

Supported Software

The following software is provided with the KUSB-3100 module:

- **Device Driver –** This software must be installed and loaded before you can use a KUSB-3100 module with any of the supported software packages or utilities.
- **The Quick Data Acq application –** This application provides a quick way to get your module up and running. Using the Quick Data Acq application, you can verify the features of the module, display data on the screen, and save data to disk.
- **DataAcq SDK –** This DT-Open Layers Software Develop Kit (SDK) allows programmers to develop application programs for the KUSB-3100 using the Microsoft C compiler in Windows 2000 or Windows XP.
- **DTx-EZ –** This software package contains ActiveX controls that allow Microsoft Visual Basic® or Visual C++® programmers to access the capabilities of the KUSB-3100 module.
- **DT-LV Link –** This software package allows LabVIEW® programmers to access the capabilities of the KUSB-3100 module.

Principles of Operation

Figure 1 shows a block diagram of the KUSB-3100 module.

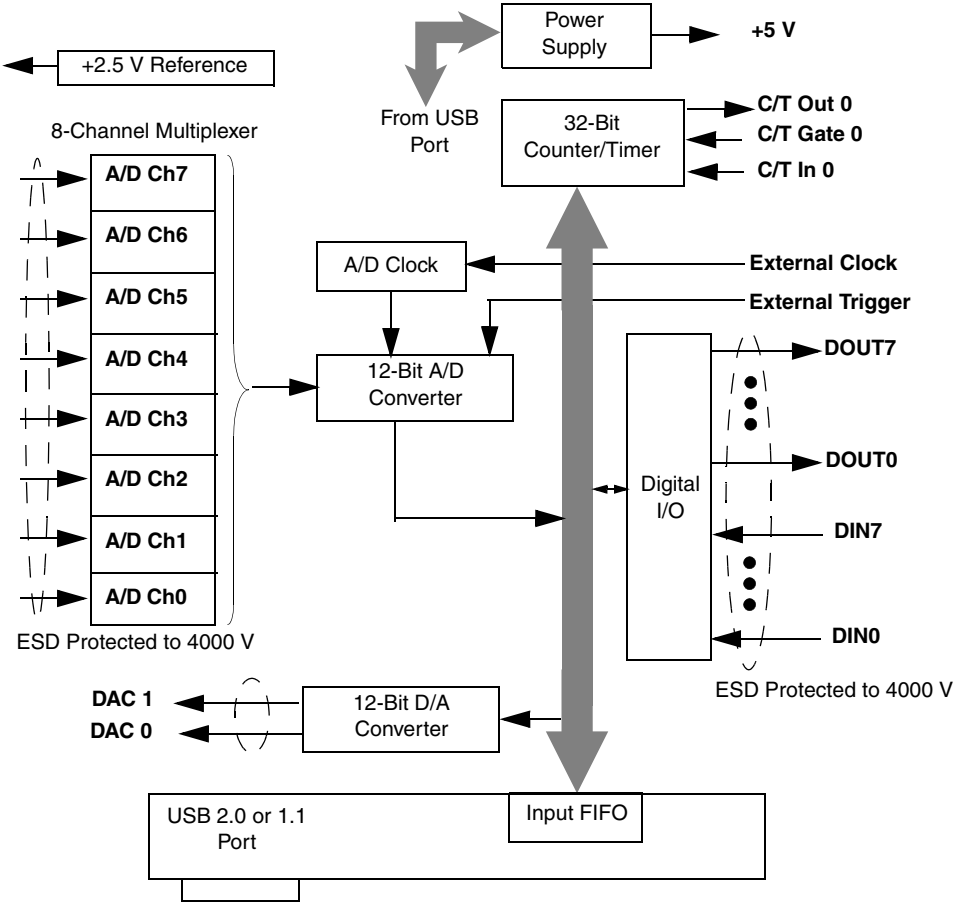


Figure 1: Block Diagram of the KUSB-3100 Module

Analog Input Features

This section describes the following features of analog input (A/D) operations on the KUSB-3100 module:

- Analog input channels, described on this page;
- Input resolution, described on page 8;
- Input ranges and gains, described on page 9;
- Input sample clock sources, described on page 10;
- Analog input conversion modes, described on page 11;
- Input triggers, described on page 13;
- Data format and transfer, described on page 14; and
- Error conditions, described on page 15.

Analog Input Channels

The KUSB-3100 module provides eight single-ended analog input channels. The module can acquire data from a single analog input channel or from a group of analog input channels.

The following subsections describe how to specify the channels.

Specifying a Single Analog Input Channel

The simplest way to acquire data from a single analog input channel is to specify the channel for a single-value analog input operation using software; refer to page 11 for more information about single-value operations.

You can also specify a single channel using the analog input channel-gain list, described in the next section.

Specifying One or More Analog Input Channels

You can read data from one or more analog input channels using an analog input channel-gain list. You can group the channels in the list sequentially (starting either with 0 or with any other analog input channel) or randomly. You can also specify a single channel or the same channel more than once in the list.

Using software, specify the channels in the order you want to sample them. You can enter up to 16 entries in the channel-gain list. The channels are read in order from the first entry in the list to the last entry in the list. Refer to page 11 for more information about the supported conversion modes.

The maximum rate at which the module can read the analog input channels is 50 kSamples/s. Therefore, if you specify two analog input channels in the channel-gain list, the maximum sampling rate is 25 kSamples/s for each channel. Likewise, if you specify 16 analog input channels in the channel-gain list, the maximum sampling rate is 3.125 kSamples/s for each channel.

Input Resolution

The KUSB-3100 module provides a resolution of 12-bits. Note that the resolution is fixed; it cannot be programmed in software.

Input Ranges and Gains

The KUSB-3100 module features an input range of ±10 V. Use software to specify the input range. Note that this is the range for the entire analog input subsystem, not the range per channel.

The KUSB-3100 module supports programmable gains to allow many more effective input ranges. Table 2 lists the supported gains and effective input ranges for each module.

Table 2: Effective Input Range

Gain	Bipolar Input Range
1	±10 V
2	±5 V
4	±2.5 V
8	±1.25 V

For each channel on the KUSB-3100 module, choose the gain that has the smallest effective range that includes the signal you want to measure. For example, if your analog input signal ranges between –2.0 V and +2.0, specify a gain of 4 for the channel; the effective input range for this channel is then –2.5 V to +2.5 V, which provides the best sampling accuracy for that channel.

The way you specify gain depends on how you specified the channels, as described in the following subsections.

Specifying the Gain for a Single Channel

The simplest way to specify gain for a single channel is to specify the gain for a single-value analog input operation using software; refer to page 11 for more information about single-value operations.

You can also specify the gain for a single channel using an analog input channel-gain list, described in the next section.

Specifying the Gain for One or More Channels

You can specify the gain for one or more analog input channels using an analog input channel-gain list. Using software, set up the channel-gain list by specifying the gain for each entry in the list.

For example, assume the analog input channel-gain list contains three entries: channels 5, 6, and 7 and gains 2, 4, and 1. A gain of 2 is applied to channel 5, a gain of 4 is applied to channel 6, and a gain of 1 is applied to channel 7.

Input Sample Clock Sources

You can use one of the following clock sources to pace an analog input operation:

- **Internal clock** – Using software, specify the clock source as internal and the clock frequency at which to pace the operation. The minimum frequency of the internal clock is 30 Hz; the maximum frequency of the internal clock is 50 kHz.

  According to sampling theory (Nyquist Theorem), specify a frequency that is at least twice as fast as the input's highest frequency component. For example, to accurately sample a 2 kHz signal, specify a sampling frequency of at least 4 kHz. Doing so avoids an error condition called *aliasing*, in which high frequency input components erroneously appear as lower frequencies after sampling.

- **External clock** – An external clock is useful when you want to pace acquisitions at rates not available with the internal clock or when you want to pace at uneven intervals. The minimum frequency of the external clock can be less than 30 Hz; the maximum frequency of the external clock is 50 kHz.

  Connect an external clock to the Ext Clock In signal on the KUSB-3100 module. Conversions start on the rising edge of the external clock input signal.

  Using software, specify the clock source as external. The clock frequency is always equal to the frequency of the external sample clock input signal that you connect to the module.

Analog Input Conversion Modes

The KUSB-3100 module supports the following conversion modes:

- Single-value operations, described on this page.
- Continuous scan operations, described on page 12.

Single-Value Operations

Single-value operations are the simplest to use. Using software, you specify the range, gain, and analog input channel. The module acquires the data from the specified channel and returns the data immediately. For a single-value operation, you cannot specify a clock source, trigger source, scan mode, or buffer.

Single-value operations stop automatically when finished; you cannot stop a single-value operation.

Continuous Scan Mode

Use continuous scan mode if you want to accurately control the period between conversions of individual channels in a channel-gain list.

When it receives a software trigger, the module cycles through the channel-gain list, acquiring and converting the data for each entry in the list (this process is defined as the scan). The module then wraps to the start of the channel-gain list and repeats the process continuously until either the allocated buffers are filled or until you stop the operation. Refer to page 14 for more information about buffers.

The conversion rate is determined by the frequency of the internal sample clock; refer to page 10 for more information about the internal sample clock. The sample rate, which is the rate at which a single entry in the channel-gain list is sampled, is determined by the frequency of the input sample clock divided by the number of entries in the channel-gain list.

To select continuous scan mode, use software to specify the data flow as continuous.

Figure 2 illustrates continuous scan mode using a channel-gain list with three entries: channel 0, channel 1, and channel 2. In this example, analog input data is acquired on each clock pulse of the input sample clock. When it reaches the end of the channel-gain list, the module wraps to the beginning of the channel-gain list and repeats this process. Data is acquired continuously.

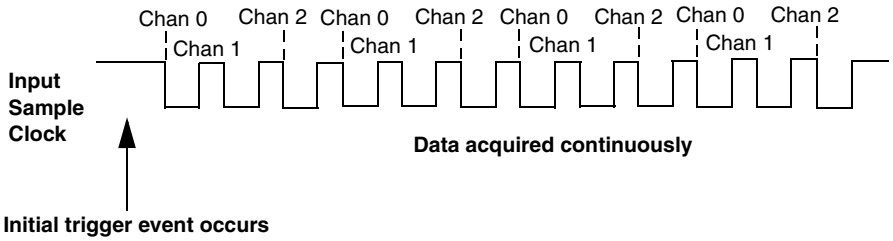


Figure 2: Continuous Scan Mode

Input Triggers

A trigger is an event that occurs based on a specified set of conditions. Acquisition starts when the module detects the initial trigger event and stops when the specified number of samples has been acquired (if the buffer wrap mode is none, described on page 14), or when you stop the operation. Note that when you stop the operation, the module completes the reading of the channel-gain list.

The KUSB-3100 module supports the following trigger sources:

- **Software trigger –** A software trigger event occurs when you start the analog input operation (the computer issues a write to the module to begin conversions). Using software, specify the trigger source as a software trigger.
- **External digital (TTL) trigger –** An external digital (TTL) trigger event occurs when the module detects a high-to-low transition on the Ext Trig In signal connected to the module. Using software, specify the trigger source as a falling-edge external digital trigger (trigger source extra).

Data Transfer

Before you begin acquiring data, you must allocate buffers to hold the data. During acquisition, a Buffer Done message is returned whenever a buffer is filled. This allows you to move and/or process the data as needed.

It is recommended that you allocate a minimum of three buffers for analog input operations, specifying one of the following buffer wrap modes in software:

- **None –** Data is written to multiple allocated input buffers continuously; when no more empty buffers are available, the operation stops. This wrap mode guarantees gap-free data.
- **Multiple –** Data is written to multiple allocated input buffers continuously; if no more empty buffers are available, the module overwrites the data in the current buffer, starting with the first location in the buffer. This process continues indefinitely until you stop it. This mode does not guarantee gap-free data.

Data Format

The KUSB-3100 module uses twos complement encoding to represent bipolar input ranges. In software, the analog input value is returned as a code.

To convert a twos complement code into a voltage, use the following formulas:

$$LSB = \frac{FSR}{2^N} = \frac{20\ V}{4096} = 0.0048828\ V$$

$$Code_{Offset\ Binary} = Code_{Twos\ Complement}\ XOR\ 2^{N-1}$$

$Vin = Code_{Offset\ Binary} * LSB + Offset$

where,

- *FSR* is the full-scale range (20 V).
- *N* is the input resolution (12 bits).
- *LSB* is the least significant bit (0.0048828 V).
- *Vin* is the analog voltage.
- $Code_{Twos\ Complement}$ is the raw count used by the software to represent the voltage in twos complement notation.
- *Offset* is the actual minus full-scale value (–10 V).
- $Code_{OffsetBinary}$ is the raw count used by the software to represent the voltage in offset binary notation.

For example, assume that the software returns a code of 3072 for the analog input value. Determine the analog input voltage as follows:

$Code_{Offset\ Binary} = Code_{Twos\ Complement}$ XOR 2^{N-1}

$Code_{Offset\ Binary}$ = 3072 XOR 2048 = 1024

Vin = 1024 * 0.0048828 V + –10 V

Vin = –5.00 V

Error Conditions

An overrun condition is reported if the A/D sample clock rate is too fast. This error is reported if a new A/D sample clock pulse occurs while the ADC is busy performing a conversion from the previous A/D sample clock pulse. It is up to the host application to handle this error either by ignoring the error or stopping acquisition. To avoid this error, use a slower sampling rate.

Analog Output Features

This section describes the following features of analog output operations:

- Analog output channels, described on this page;
- Output resolution, described on page 17;
- Output ranges and gains, described on page 17;
- Output trigger, described on page 17,
- Output clock, described on page 18,
- Data format and transfer, described on page 21; and
- Error conditions, described on page 22.

Analog Output Channels

The KUSB-3100 module provides two analog output channels (DACs). The module can output data from a single analog output channel or from both analog output channels.

The following subsections describe how to specify the channels.

Specifying a Single Analog Output Channel

The simplest way to output data from a single analog output channel is to use single-value analog output mode, specifying the analog output channel that you want to update; refer to page 18 for more information about single-value operations.

You can also specify a single analog output channel using the output channel list, described in the next section.

Specifying Analog Output Channels

You can output data continuously from one or both analog output channels using the output channel list. If you want to output data from one analog output channel continuously, specify either 0 (DAC0) or 1 (DAC1) in the channel output list. If you want to output data to both analog output channels continuously, specify the output channel list in the following order: 0, 1.

Then, use software to specify the data flow mode as continuous for the D/A subsystem; refer to page 18 for more information on continuous analog output operations.

Output Resolution

The KUSB-3100 module provides a fixed output resolution of 12 bits. Note that the resolution is fixed; it cannot be programmed in software.

Output Ranges and Gains

The KUSB-3100 module provides a fixed output range of ±10 V (the gain is ignored).

Output Trigger

A trigger is an event that occurs based on a specified set of conditions. The KUSB-3100 module supports a software trigger for starting analog output operations. The module starts outputting data when it receives a software command (trigger).

Use software to specify the trigger source for the D/A subsystem as a software trigger.

Output Clock

When in continuous output mode, described on page 19, you can update both analog output channels simultaneously using the internal clock on the KUSB-3100 module.

Using software, specify the clock source for the D/A subsystem as internal and specify a frequency between 30 Hz to 50 kHz at which to update the analog output channels.

Note: The output clock frequency that you specify is the frequency at which both analog output channels are simultaneously updated.

Output Conversion Modes

The KUSB-3100 module supports the following output conversion modes:

- Single-value output operations, described on this page.
- Continuous output operations, described on page 19.

Single-Value Operations

Single-value operations are the simplest to use but offer the least flexibility and efficiency. Use software to specify the analog output channel, and the value to output from the analog output channel. Since a single-value operation is not clocked, you cannot specify a clock source, trigger source, or buffer.

Single-value operations stop automatically when finished; you cannot stop a single-value operation.

Continuous Output Mode

Use continuously paced analog output mode if you want to accurately control the period between D/A conversions or write a waveform to one or more analog output channels.

Use software to configure the output channel list, as described on page 16. Then, allocate a buffer that contains the values to write to the analog output channels that are specified in the output channel list. For example, if your output channel list contains DAC0 and DAC1, specify your buffer as follows: first value for DAC0, first value for DAC1, second value for DAC0, second value for DAC1, and so on.

When it receives the software trigger, the module starts writing output values to the analog output channels specified in the output channel list. The operation repeats continuously until either all the data is output from the buffers (if buffer wrap mode is none) or you stop the operation (if buffer wrap mode is multiple). Refer to page 21 for more information about buffer modes.

Note: Make sure that the host computer transfers data to the analog output channels fast enough so that they do not empty completely; otherwise, an underrun error results.

To select continuously paced analog output mode, use software to specify the data flow as continuous, the buffer wrap mode as none or multiple, the trigger source and output clock as internal, and the output clock frequency (between 30 Hz and 50 kHz).

To stop a continuously paced analog output operation, you can stop sending data to the module, letting the module stop when it runs out of data, or you can perform either an orderly stop or an abrupt stop using software. In an orderly stop, the module finishes outputting the specified number of samples, then stops; all subsequent triggers are ignored. In an abrupt stop, the module stops outputting samples immediately; all subsequent triggers are ignored.

Data Transfer

If you are using continuous output mode, you must allocate and fill multiple buffers with the appropriate data before starting the operation, and specify one of the following buffer wrap modes in software:

- **None –** Data is written from multiple output buffers continuously; when no more buffers of data are available, the continuous output operation stops. This mode guarantees gap-free data.
- **Multiple –** Data is written from multiple output buffers continuously; when no more buffers of data are available, the module returns to the first location of the first buffer and continues writing data. This process continues indefinitely until you stop it. This mode does not guarantee gap-free data.

A Buffer Done message is returned whenever the last value in a buffer is output. This allows you to fill the buffer or provide a new buffer, as needed.

Note: An underrun error can result if your buffer size is too small, if you do not allocate enough buffers, or if your output frequency is too fast.

Data Format

The KUSB-3100 module uses twos complement encoding for analog output values. In software, you need to supply a code that corresponds to the analog output value to output.

To convert a voltage into a twos complement code, use the following formulas:

$$LSB = \frac{FSR}{2^N} = \frac{20\ V}{4096} = 0.0048828\ V$$

$$Code_{Offset\ Binary} = \frac{Vout - Offset}{LSB}$$

$$Code_{Twos\ Complement} = Code_{Offset\ Binary}\ XOR\ (2^{N-1})$$

where,

- *FSR* is the full-scale range (20 V).
- *N* is the input resolution (12 bits).
- *LSB* is the least significant bit (0.0048828).
- *Vout* is the analog voltage.
- *Offset* is the actual minus full-scale value (–10.0 V).
- $Code_{OffsetBinary}$ is the raw count used by the software to represent the voltage in offset binary notation.
- $Code_{Twos\ Complement}$ is the raw count used by the software to represent the voltage in twos complement notation.

$$Code_{Offset\ Binary} = \frac{Vout - Offset}{LSB}$$

$$Code_{OffsetBinary} = \frac{+5\ V - (-10\ V)}{0.0048828\ V} = 3072$$

$$Code_{Twos\ Complement} = 3072\ XOR\ 2048$$

$$Code_{Twos\ Complement} = 1024$$

Error Conditions

The KUSB-3100 module can report an underrun error if the data for the analog output channels is not sent fast enough from the host computer. It is up to the host application to handle this error either by ignoring it or by stopping the output operation.

To avoid this error, try slowing down the output frequency, increasing the output buffer size, or allocating more output buffers.

Note: If no new data is available to be output by the analog output channels, the last value that was written to the analog output channels continues to be output by the analog output channels.

Digital I/O Features

This section describes the following features of digital I/O operations:

- Digital I/O lines, described on this page;
- Resolution, described on page 23, and
- Operation modes, described on page 24.

Digital I/O Lines

The KUSB-3100 module provides 8 dedicated digital input lines and 8 dedicated digital output lines.

Using DT-Open Layers, you can specify the digital line that you want to read or write in a single-value digital I/O operation. Refer to page 24 for more information about single-value operations.

A digital line is high if its value is 1; a digital line is low if its value is 0. On power up or reset, a low value (0) is output from each of the digital output lines.

Note: You can also read or write to the digital I/O lines using direct register calls. Refer to Appendix C for more information on these calls.

Resolution

The resolution of the digital ports on the KUSB-3100 module is fixed at 8-bits.

Operation Modes

The KUSB-3100 module supports single-value digital I/O operations only. For a single-value operation, use software to specify digital input port A or digital output port A (the gain is ignored). Data is then read from or written to the digital lines associated with that port.

Single-value operations stop automatically when finished; you cannot stop a single-value operation.

Counter/Timer Features

This section describes the following features of counter/timer (C/T) operations:

- C/T channels, described on this page;
- C/T clock sources, described on page 26;
- Gate types, described on page 26;
- Pulse types and duty cycles, described on page 27; and
- C/T operation modes, described on page 28.

C/T Channels

The KUSB-3100 module provides one 32-bit counter/timer (16 bits in rate generation mode). The counter accepts a C/T clock input signal (pulse input signal) and gate input signal, and outputs a pulse signal (clock output signal), as shown in Figure 3.

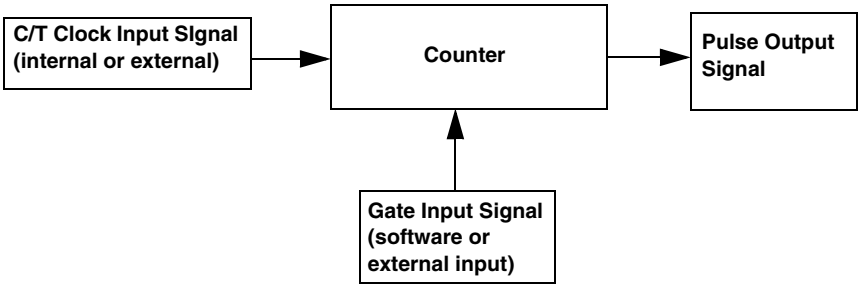


Figure 3: Counter/Timer Channel

C/T Clock Sources

The following clock sources are available for the counter/timers:

- **Internal clock** – The internal clock uses a 24 MHz time base. Through software, specify the clock source as internal, and specify the frequency at which to pace the counter/timer operation. The frequency of the internal C/T clock can range from 15 Hz to 12 MHz.
- **External clock** – An external clock is useful when you want to pace counter/timer operations at rates not available with the internal clock or if you want to pace at uneven intervals.

  Connect an external clock with a maximum recommended frequency of 6 MHz to the Counter 0 In signal on the KUSB-3100 module. Using software, specify the C/T clock source as external, and specify a clock divider between 2 and 65536 to determine the actual frequency at which to pace the counter/timer operation. For example, if you connect a 6 MHz external C/T clock and use a clock divider of 2, the resulting C/T output frequency is 3 MHz. Counter/timer operations start on the falling edge of the Counter 0 In signal.

Gate Types

The edge or level of the Counter 0 Gate signal determines when a counter/timer operation is enabled. Using software, you can specify one of the following gate types:

- **None –** A software command enables any counter/timer operation immediately after execution.
- **Logic-high level external gate input –** Enables a counter/timer operation when Counter 0 Gate is high, and disables a counter/timer operation when Counter 0 Gate is low. Note that this gate type is used for event counting and rate generation modes; refer to page 28 for more information about these modes.

- **Falling-edge external gate input –** Enables a counter/timer operation when a high-to-low transition is detected on the Counter 0 Gate signal. In software, this is called a low-edge gate type. Note that this gate type is used for edge-to-edge measurement mode; refer to page 30 for more information about these modes.
- **Rising-edge external gate input –** Enables a counter/timer operation when a low-to-high transition is detected on the Counter 0 Gate signal. In software, this is called a high-edge gate type. Note that this gate type is used for edge-to-edge measurement operations; refer to page 30 for more information about these modes.

Pulse Duty Cycles

Counter/timer output signals from the KUSB-3100 module are high-to-low going signals.

The duty cycle (or pulse width) indicates the percentage of the total pulse output period that is active. In rate generation mode, the duty cycle is fixed at 50% for the KUSB-3100 module. Figure 4 illustrates a high-to-low going output pulse with a duty cycle of 50%.

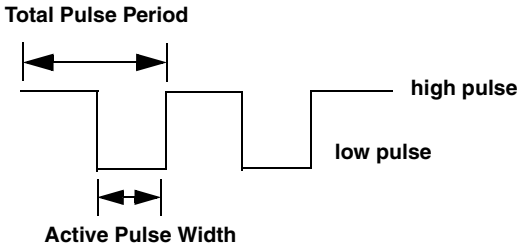


Figure 4: Example of a Pulse Output SIgnal with a 50% Duty Cycle (High-to-Low Going)

Counter/Timer Operation Modes

The KUSB-3100 module supports the following counter/timer operation modes:

- Event counting, described on this page.
- Frequency measurement, described on page 29.
- Edge-to-edge measurement, described on page 30.
- Rate generation, described on page 31.

Event Counting

Use event counting mode if you want to count the number of falling edges that occur on Counter 0 In when the gate is active (high-level gate or software gate). Refer to page 26 for information about specifying the active gate type.

You can count a maximum of 4,294,967,296 events before the counter rolls over to 0 and starts counting again.

For event counting operations, use software to specify the counter/timer mode as count, the C/T clock source as external, and the active gate type as software or high-level.

Make sure that the signals are wired appropriately. Refer to the *KUSB-3100 Getting Started Manual* for an example of connecting an event counting application.

Frequency Measurement

Using software, specify the counter/timer mode as count, the clock source as external, and the time over which to measure the frequency.

To specify the duration, you can use the Windows timer (which uses a resolution of 1 ms), or if you need more accuracy than the Windows timer provides, you can connect a pulse of a known duration to the Counter 0 Gate signal.

If you are using a known pulse for the duration, specify the active gate in software (high level or low level). When the operation starts, read the number of counts that occurred when the gate was active.

You can determine the measurement period using the following equation:

$$\text{Measurement period} = \frac{1}{\text{Clock Frequency}} * \text{Active Pulse Width}$$

You can determine the frequency of the clock input signal using the following equation:

$$\text{Frequency Measurement} = \frac{\text{Number of Events}}{\text{Measurement Period}}$$

Make sure that the signals are wired appropriately. Refer to the *KUSB-3100 Getting Started Manual* for an example of connecting a frequency measurement application.

Edge-to-Edge Measurement

Use edge-to-edge measurement mode if you want to measure the time interval between a specified start edge and a specified stop edge.

The start edge can occur on the rising edge or the falling edge of the Counter 0 Gate signal, and the stop edge can occur on the rising edge or the falling edge of the Counter 0 Gate signal. When the start edge is detected, the counter/timer starts incrementing and continues incrementing until the stop edge is detected. The C/T then stops incrementing until it is enabled to start another measurement. When the operation is complete, you can read the value of the counter. You can count a maximum of 4,294,967,296 events before the counter rolls over to 0 and starts counting again.

You can use edge-to-edge measurement to measure the following characteristics of a signal:

- Pulse width – The amount of time that a signal pulse is in a high or a low state, or the amount of time between a rising edge and a falling edge or between a falling edge and a rising edge. You can calculate the pulse width as follows:
  - Pulse width = Number of counts/24 MHz
- Period – The time between two occurrences of the same edge (rising edge to rising edge, or falling edge to falling edge). You can calculate the period as follows:
  - Period = 1/Frequency
  - Period = Number of counts/24 MHz
- Frequency – The number of periods per second. You can calculate the frequency as follows:
  - Frequency = 24 MHz/Number of Counts

Using software, specify the counter/timer mode as measure, the C/T clock source as internal, the start edge as rising or falling gate, and the stop edge as rising or falling gate.

Make sure that the signals are wired appropriately. Refer to the *KUSB-3100 Getting Started Manual* for an example of connecting an edge-to-edge measurement application.

Rate Generation

Use rate generation mode to generate a continuous pulse output signal from Counter 0 Out; this mode is sometimes referred to as continuous pulse output or pulse train output.

The pulse output operation is enabled whenever the Counter 0 Gate signal is active (high level, low level, or software gate). While the pulse output operation is enabled, the counter outputs a high-to-low going pulse with a pulse width of 50% continuously. As soon as the operation is disabled, rate generation stops.

The period of the output pulse is determined by the C/T clock source (either internal or external) and the clock divider used. You can generate an output signal from Counter 0 Out with a frequency of 15 Hz to 12 MHz.

To specify rate generation mode, use software to specify the counter/timer mode as rate, the C/T clock source as either internal or external, the clock divider (2 to 65536), and the active gate type (high-level or software gate). Refer to page 26 for more information about gate types.

Make sure that the signals are wired appropriately. Refer to the *KUSB-3100 Getting Started Manual* for an example of connecting a rate generation application.

Supported Device Driver Capabilities

The device driver for the KUSB-3100 module supports A/D, D/A, DIN, DOUT, and C/T subsystems. For information on how to configure the device driver, refer to the *KUSB-3100 Getting Started Manual.*

Table 3 summarizes the features available for use with the DataAcq SDK and the KUSB-3100 module. The DataAcq SDK provides functions that return support information for specified subsystem capabilities at run-time.

The first row in the table lists the subsystem types. The first column in the table lists all possible subsystem capabilities. A description of each capability is followed by the parameter used to describe that capability in the DataAcq SDK.

Note: Blank fields represent unsupported options.

The DataAcq SDK uses the functions **olDaGetSSCaps** (for those queries starting with OLSSC) and **olDaGetSSCapsEx** (for those queries starting with OLSSCE) to return the supported subsystem capabilities for a device.

For more information, refer to the description of these functions in the DataAcq SDK online help. See the *DataAcq User's Manual* for information on launching this help file.

Table 3: KUSB-3100 Supported Options

	KUSB-3100	A/D	D/A	DIN	DOUT	SRL	C/T
	Total Subsystems on Module	**1**	**1**	**1[a]**	**1[b]**	**0**	**1**
Data Flow Mode	Single-Value Operation Support OLSSC_SUP_SINGLEVALUE	Yes	Yes	Yes	Yes		
	Continuous Operation Support OLSSC_SUP_CONTINUOUS	Yes	Yes				Yes
	Continuous Operation until Trigger Event Support OLSSC_SUP_CONTINUOUS_PRETRIG						
	Continuous Operation before and after Trigger Event OLSSC_SUP_CONTINUOUS_ ABOUTTRIG						
	DT-Connect Support OLSSC_SUP_DTCONNECT						
	Continuous DT-Connect Support OLSSC_SUP_DTCONNECT_ CONTINUOUS						
	Burst DT-Connect Support OLSSC_SUP_DTCONNECT_BURST						
Sim. Oper.	Simultaneous Start List Support OLSSC_SUP_SIMULTANEOUS_START	Yes	Yes				
Pause Oper.	Pause Operation Support OLSSC_SUP_PAUSE						
Wind. Mess.	Asynchronous Operation Support OLSSC_SUP_POSTMESSAGE	Yes	Yes				Yes
Buffering	Buffer Support OLSSC_SUP_BUFFERING	Yes	Yes				
	Single Buffer Wrap Mode Support OLSSC_SUP_WRPSINGLE						

Table 3: KUSB-3100 Supported Options (cont.)

	KUSB-3100	A/D	D/A	DIN	DOUT	SRL	C/T
	Total Subsystems on Module	**1**	**1**	**1[a]**	**1[b]**	**0**	**1**
Buffering (cont.)	Multiple Buffer Wrap Mode Support OLSSC_SUP_WRPMULTIPLE	Yes	Yes				
	Inprocess Buffer Flush Support OLSSC_SUP_INPROCESSFLUSH	Yes					
DMA	Number of DMA Channels OLSSC_NUMDMACHANS	0	0	0	0		0
	Supports Gap Free Data with No DMA OLSSC_SUP_GAPFREE_NODMA	Yes					
	Supports Gap Free Data with Single DMA OLSSC_SUP_GAPFREE_SINGLEDMA						
	Supports Gap Free Data with Dual DMA OLSSC_SUP_GAPFREE_DUALDMA						
Triggered Scan Mode	Triggered Scan Support OLSSC_SUP_TRIGSCAN						
	Maximum Number of CGL Scans per Trigger OLSSC_MAXMULTISCAN	1	0	0	0		0
	Supports Scan per Trigger Event Triggered Scan OLSSC_SUP_RETRIGGER_SCAN_PER_TRIGGER						
	Supports Internal Retriggered Triggered Scan OLSSC_SUP_RETRIGGER_INTERNAL						
	Extra Retrigger Support OLSSC_SUP_RETRIGGER_EXTRA						

Table 3: KUSB-3100 Supported Options (cont.)

	KUSB-3100	A/D	D/A	DIN	DOUT	SRL	C/T
	Total Subsystems on Module	**1**	**1**	**1[a]**	**1[b]**	**0**	**1**
Trig. Scan Mode (cont.)	Maximum Retrigger Frequency OLSSCE_MAXRETRIGGER	0	0	0	0		0
	Minimum Retrigger Frequency OLSSCE_MINRETRIGGER	0	0	0	0		0
Channel-Gain List	Maximum Channel-Gain List Depth OLSSC_CGLDEPTH	16	2	0	0		0
	Sequential Channel-Gain List Support OLSSC_SUP_SEQUENTIAL_CGL	Yes	Yes				
	Zero Start Sequential Channel-Gain List Support OLSSC_SUP_ZEROSEQUENTIAL_CGL	Yes	Yes				
	Random Channel-Gain List Support OLSSC_SUP_RANDOM_CGL	Yes					
	Simultaneous Sample-and-Hold Support OLSSC_SUP_SIMULTANEOUS_SH						
	Channel List Inhibit Support OLSSC_SUP_CHANNELLIST_INHIBIT						
Gain	Programmable Gain Support OLSSC_SUP_PROGRAMGAIN	Yes					
	Number of Gains OLSSC_NUMGAINS	4[c]	1	1	1		0
	AutoRanging Support OLSSC_SINGLEVALUE_AUTORANGE						
Synchronous Digital I/O	Synchronous Digital I/O Support OLSSC_SUP_SYNCHRONOUS_DIGITALIO						
	Maximum Synchronous Digital I/O Value OLSSC_MAXDIGITALIOLIST_VALUE	0	0	0	0		0

Table 3: KUSB-3100 Supported Options (cont.)

	KUSB-3100	A/D	D/A	DIN	DOUT	SRL	C/T
	Total Subsystems on Module	**1**	**1**	**1[a]**	**1[b]**	**0**	**1**
I/O Channels	Number of Channels OLSSC_NUMCHANNELS	8	2	1	1		1
	Channel Expansion Support OLSSC_SUP_EXP2896						
	Channel Expansion OLSSC_SUP_EXP727						
Channel Type	SE Support OLSSC_SUP_SINGLEENDED	Yes	Yes				
	SE Channels OLSSC_MAXSECHANS	8	2	0	0		0
	DI Support OLSSC_SUP_DIFFERENTIAL			Yes	Yes		Yes
	DI Channels OLSSC_MAXDICHANS			1	1		1
Filters	Filter/Channel Support OLSSC_SUP_FILTERPERCHAN						
	Number of Filters OLSSC_NUMFILTERS	1	1	1	1		0
Ranges	Number of Voltage Ranges OLSSC_NUMRANGES	1[c]	1	0	0		0
	Range per Channel Support OLSSC_SUP_RANGEPERCHANNEL						
Resolution	Software Programmable Resolution OLSSC_SUP_SWRESOLUTION						
	Number of Resolutions OLSSC_NUMRESOLUTIONS	1[d]	1[d]	1[e]	1[e]		1
Data Encoding	Binary Encoding Support OLSSC_SUP_BINARY			Yes	Yes		Yes
	Twos Complement Support OLSSC_SUP_2SCOMP	Yes[f]	Yes[f]				

Table 3: KUSB-3100 Supported Options (cont.)

	KUSB-3100	A/D	D/A	DIN	DOUT	SRL	C/T
	Total Subsystems on Module	**1**	**1**	**1[a]**	**1[b]**	**0**	**1**
Triggers	Software Trigger Support OLSSC_SUP_SOFTTRIG	Yes	Yes				Yes
	External Trigger Support OLSSC_SUP_EXTERNTRIG	Yes[g]					Yes
	Positive Threshold Trigger Support OLSSC_SUP_THRESHTRIGPOS						
	Negative Threshold Trigger Support OLSSC_SUP_THRESHTRIGNEG						
	Analog Event Trigger Support OLSSC_SUP_ANALOGEVENTTRIG						
	Digital Event Trigger Support OLSSC_SUP_DIGITALEVENTTRIG						
	Timer Event Trigger Support OLSSC_SUP_TIMEREVENTTRIG						
	Number of Extra Triggers OLSSC_NUMEXTRATRIGGERS	1[g]	0	0	0		0
Clocks	Internal Clock Support OLSSC_SUP_INTCLOCK	Yes	Yes				Yes
	External Clock Support OLSSC_SUP_EXTCLOCK	Yes					Yes
	Simultaneous Input/Output on a Single Clock Signal OLSSC_SUP_SIMULTANEOUS_CLOCKING		Yes				
	Number of Extra Clocks OLSSC_NUMEXTRACLOCKS	0	0	0	0		0
	Base Clock Frequency OLSSCE_BASECLOCK	24 MHz	24 MHz	0	0		24 MHz
	Maximum External Clock Divider OLSSCE_MAXCLOCKDIVIDER	1	1	1	1		65536

Table 3: KUSB-3100 Supported Options (cont.)

	KUSB-3100	A/D	D/A	DIN	DOUT	SRL	C/T
	Total Subsystems on Module	**1**	**1**	**1[a]**	**1[b]**	**0**	**1**
Clocks (cont.)	Minimum External Clock Divider OLSSCE_MINCLOCKDIVIDER	1	1	1	1		2
	Maximum Throughput OLSSCE_MAXTHROUGHPUT	50 kHz	50 kHz	0	0		12 MHz
	Minimum Throughput OLSSCE_MINTHROUGHPUT	30 Hz	30 Hz	0	0		15 Hz
Counter/Timers	Cascading Support OLSSC_SUP_CASCADING						
	Event Count Mode Support OLSC_SUP_CTMODE_COUNT						Yes
	Generate Rate Mode Support OLSSC_SUP_CTMODE_RATE						Yes
	One-Shot Mode Support OLSSC_SUP_CTMODE_ONESHOT						
	Repetitive One-Shot Mode Support OLSSC_SUP_CTMODE_ONESHOT_RPT						
	Up/Down Counting Mode Support OLSC_SUP_CTMODE_UP_DOWN						
	Edge-to-Edge Measurement Mode Support OLSSC_SUP_CTMODE_MEASURE						3[h]
	Continuous Edge-to-Edge Measurement Mode Support OLSSC_SUP_CTMODE_CONT_MEASURE						
	Fixed Pulse Width OLSSC_FIXED_PULSE_WIDTH						Yes[i]
	High to Low Output Pulse Support OLSSC_SUP_PLS_HIGH2LOW						Yes

Table 3: KUSB-3100 Supported Options (cont.)

	KUSB-3100	A/D	D/A	DIN	DOUT	SRL	C/T
	Total Subsystems on Module	**1**	**1**	**1[a]**	**1[b]**	**0**	**1**
Counter/Timers (cont.)	Low to High Output Pulse Support OLSSC_SUP_PLS_LOW2HIGH						
	None (internal) Gate Type Support OLSSC_SUP_GATE_NONE						Yes
	High Level Gate Type Support OLSSC_SUP_GATE_HIGH_LEVEL						Yes
	Low Level Gate Type Support OLSSC_SUP_GATE_LOW_LEVEL						
	High Edge Gate Type Support OLSSC_SUP_GATE_HIGH_EDGE						Yes
	Low Edge Gate Type Support OLSSC_SUP_GATE_LOW_EDGE						Yes
	Level Change Gate Type Support OLSSC_SUP_GATE_LEVEL						
	High Level Gate Type with Input Debounce Support OLSSC_SUP_GATE_HIGH_LEVEL_DEBOUNCE						
	Low Level Gate Type with Input Debounce Support OLSSC_SUP_GATE_LOW_LEVEL_DEBOUNCE						
	High Edge Gate Type with Input Debounce Support OLSSC_SUP_GATE_HIGH_EDGE_DEBOUNCE						
	Low Edge Gate Type with Input Debounce Support OLSSC_SUP_GATE_LOW_EDGE_DEBOUNCE						

Table 3: KUSB-3100 Supported Options (cont.)

	KUSB-3100	A/D	D/A	DIN	DOUT	SRL	C/T
	Total Subsystems on Module	**1**	**1**	**1[a]**	**1[b]**	**0**	**1**
Counter/Timers (cont.)	Level Change Gate Type with Input Debounce Support OLSSC_SUP_GATE_LEVEL_DEBOUNCE						
Interrupt	Interrupt Support OLSSC_SUP_INTERRUPT						Yes
FIFOs	FIFO in Data Path Support OLSSC_SUP_FIFO		Yes				
	Output FIFO Size OLSSC_FIFO_SIZE_IN_K		2[j]				
Processor	Data Processing Capability OLSSC_SUP_PROCESSOR	Yes	Yes				
Software Calibration	Software Calibration Support OLSSC_SUP_SWCAL	Yes[k]	Yes[k]				

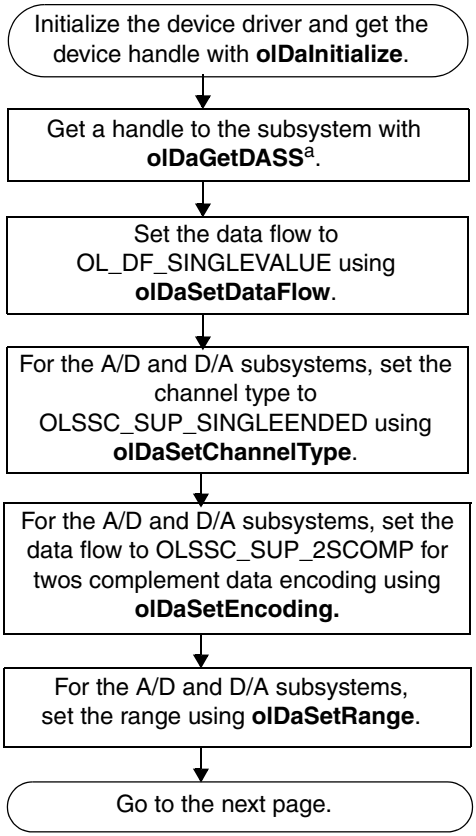
a. The DIN subsystem contains eight digital input lines(0 to 7).
b. The DOUT subsystem contains eight digital output lines (0 to 7).
c. The KUSB-3100 module has a full-scale input range of ±10 V and supports gains of 1, 2, 4, and 8 to provide many effective input ranges. Refer to page 9 for more information on gains and input ranges.
d. The KUSB-3100 module supports a fixed A/D and D/A resolution of 12-bits.
e. The resolution of the digital input port (port A) is fixed at 8-bits or eight digital input lines. The resolution of the digital output port (port A) is fixed at 8-bits or eight digital output lines.
f. The KUSB-3100 module supports twos complement data encoding for the A/D and D/A subsystems.
g. The external digital trigger input (trigger source is OL_TRG_EXTRA) is active on the falling edge (high-to-low transition) of the TTL signal.
h. Edge-to-edge measurement is supported on the gate signal only; both rising and falling edges are supported.
i. The pulse width (duty cycle) if fixed at 50% when rate generation mode is used.
j. A 2K FIFO is used by the D/A subsystem; a 1K FIFO is used by the A/D subsystem.
k. A calibration utility, described in Chapter 6, is provided for the KUSB-3100.

Programming Flowcharts

The following flowcharts show the steps required to perform data acquisition operations using DT-Open Layers. For illustration purposes, the DataAcq SDK functions are shown; however, the concepts apply to all DT-Open Layers software.

Note that many steps represent several substeps; if you are unfamiliar with the detailed operations involved with any one step, refer to the indicated page for detailed information. Optional steps appear in shaded boxes.

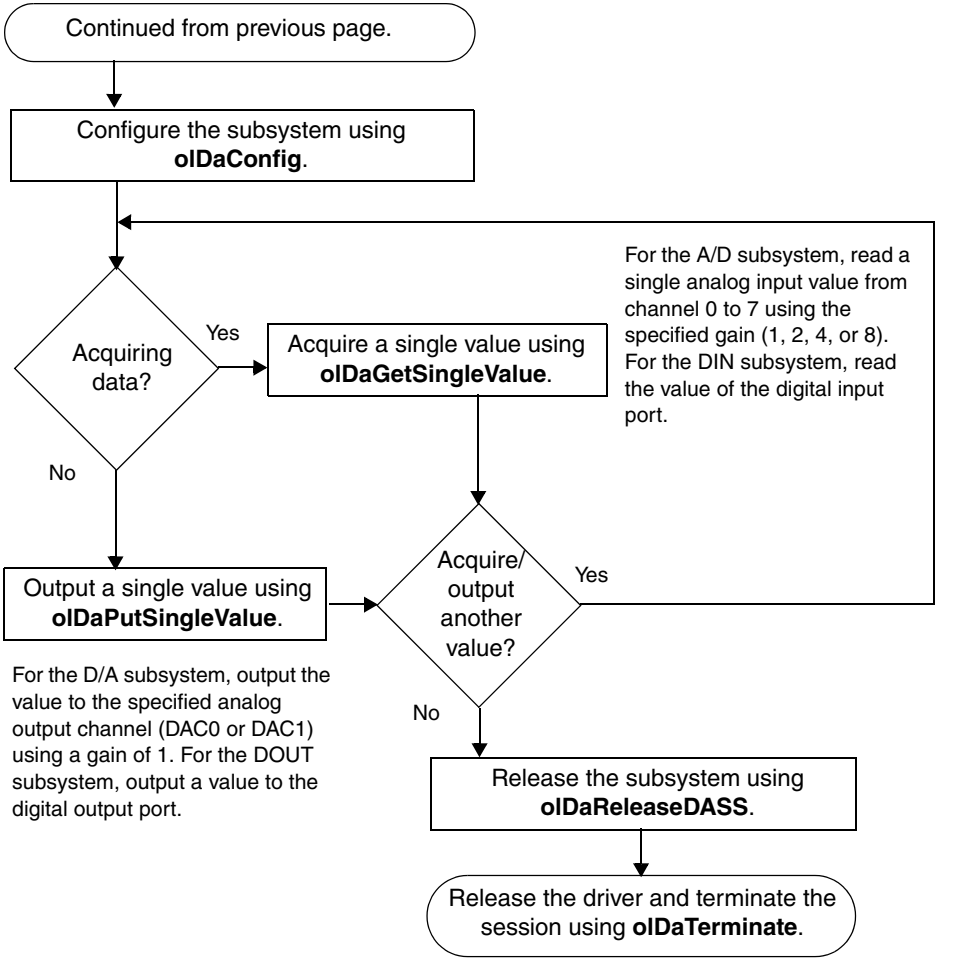
Single-Value Operations



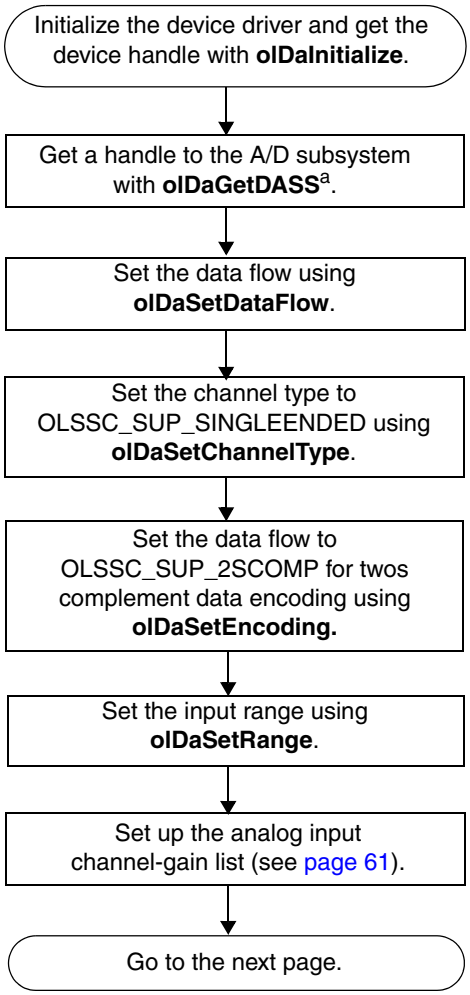
[a] Specify A/D subsystem 0 for an analog input operation, D/A subsystem 0 for an analog output operation, DIN subsystem 0 for a digital input operation, or DOUT subsystem 0 for a digital output operation.

The resolution of the A/D and D/A subsystems is fixed at 12-bits. The resolution of the DIN and DOUT subsystems is fixed at 8-bits.

Single-Value Operations (cont.)

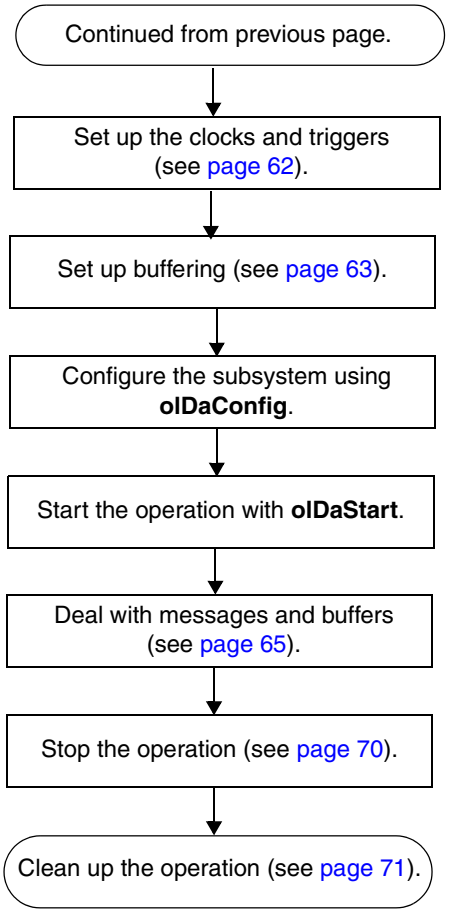


Continuous A/D Operations



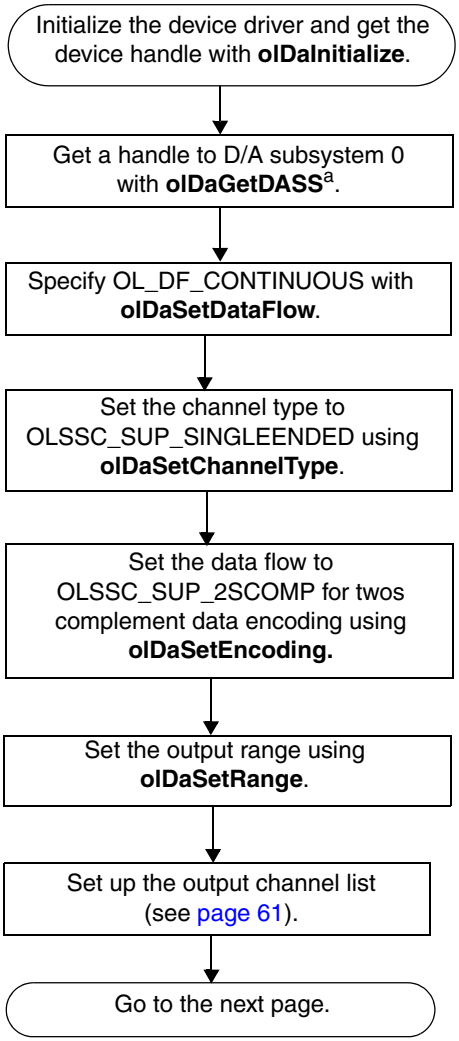
[a] Specify A/D subsystem 0 for an analog input operation. This subsystem supports analog input channels 0 to 7. The resolution of the A/D subsystem is fixed at 12-bits.

Continuous A/D Operations (cont.)



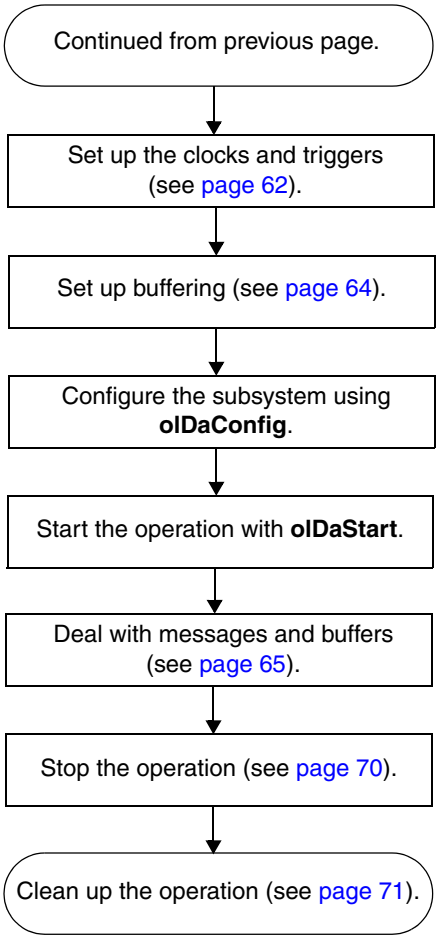
After you configure the subsystem, you can use **olDaGetClockFrequency** to return the actual frequency of the internal clock.

Continuous D/A Operations

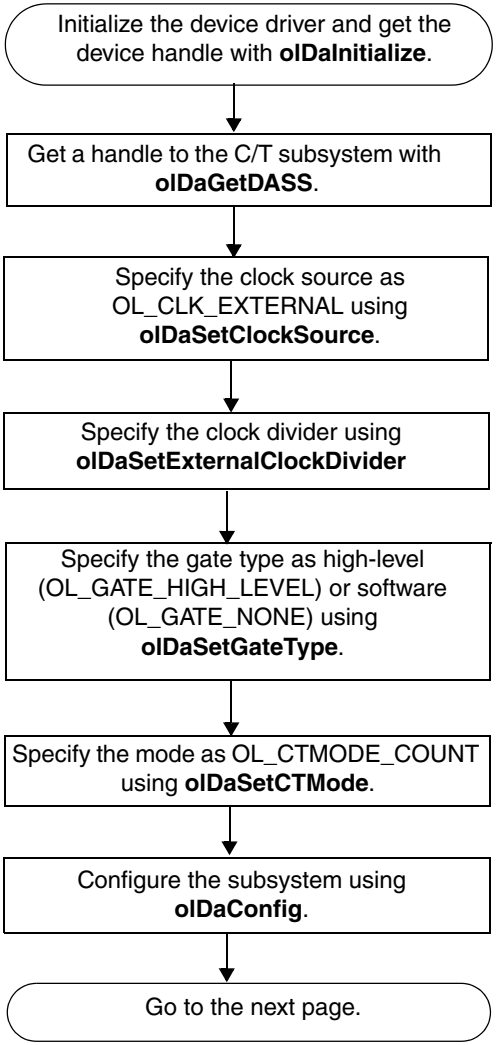


[a] Specify D/A subsystem 0 for an analog output operation. This subsystem supports analog output channels DAC0 and DAC1. The resolution of the D/A subsystem is fixed at 12-bits.

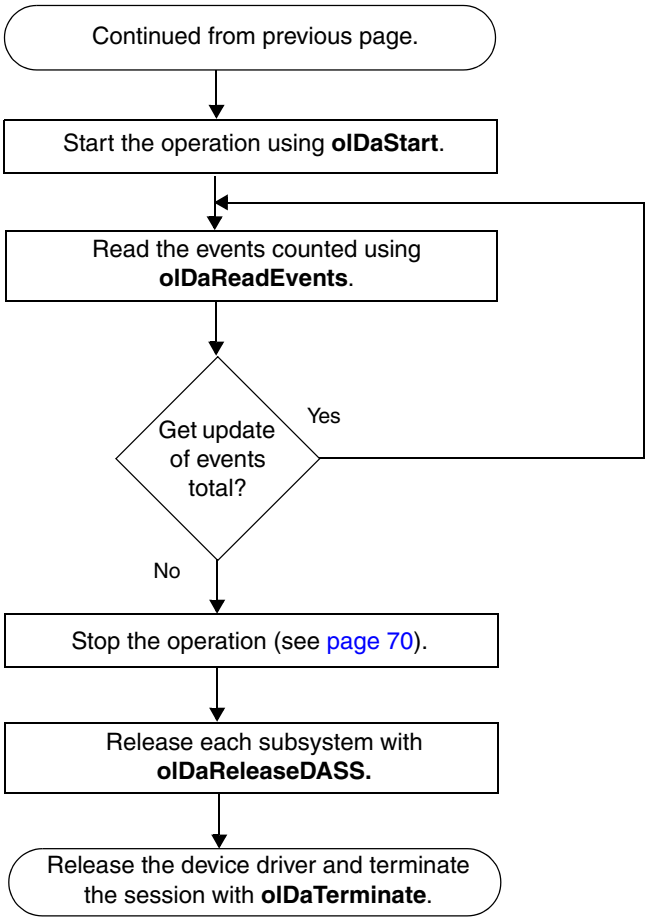
Continuous D/A Operations (cont.)



Event Counting Operations

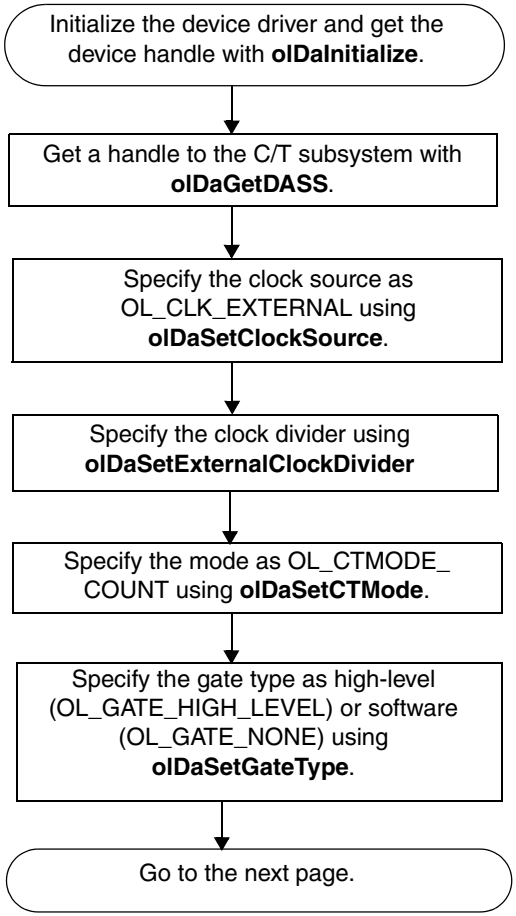


Event Counting Operations (cont.)

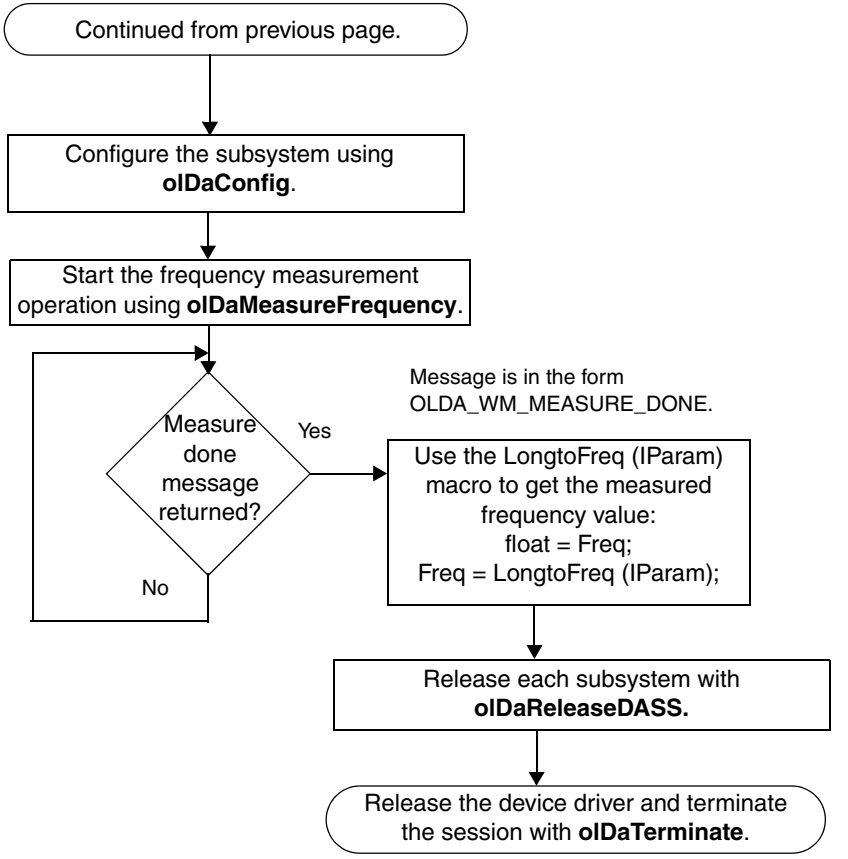


Frequency Measurement Operations

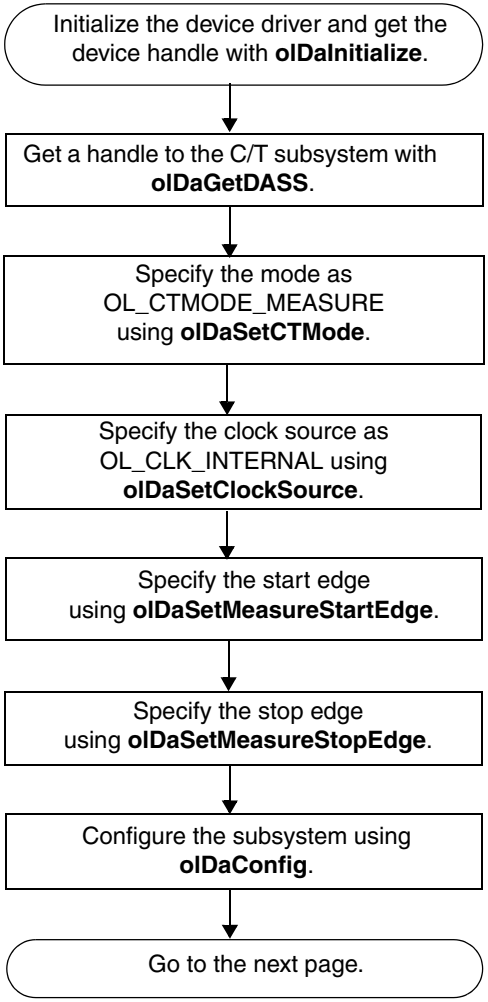
The following flowchart shows the steps required to perform a frequency measurement operation using the Windows timer. If you need more accuracy the Windows timer provides, refer to page 23 of this manual or to your *DataAcq SDK User's Manual* for more information.



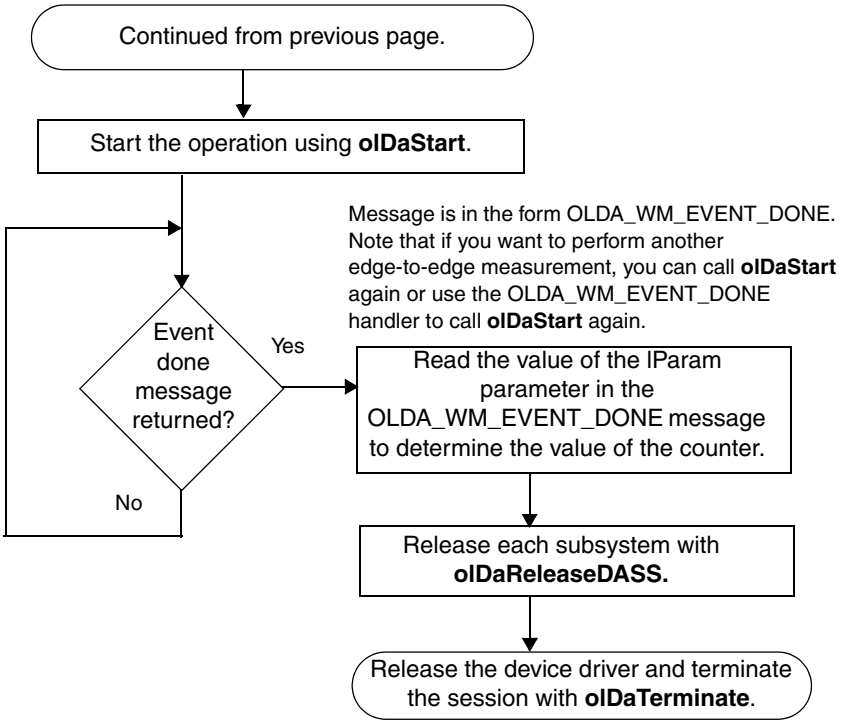
Frequency Measurement Operations (cont.)



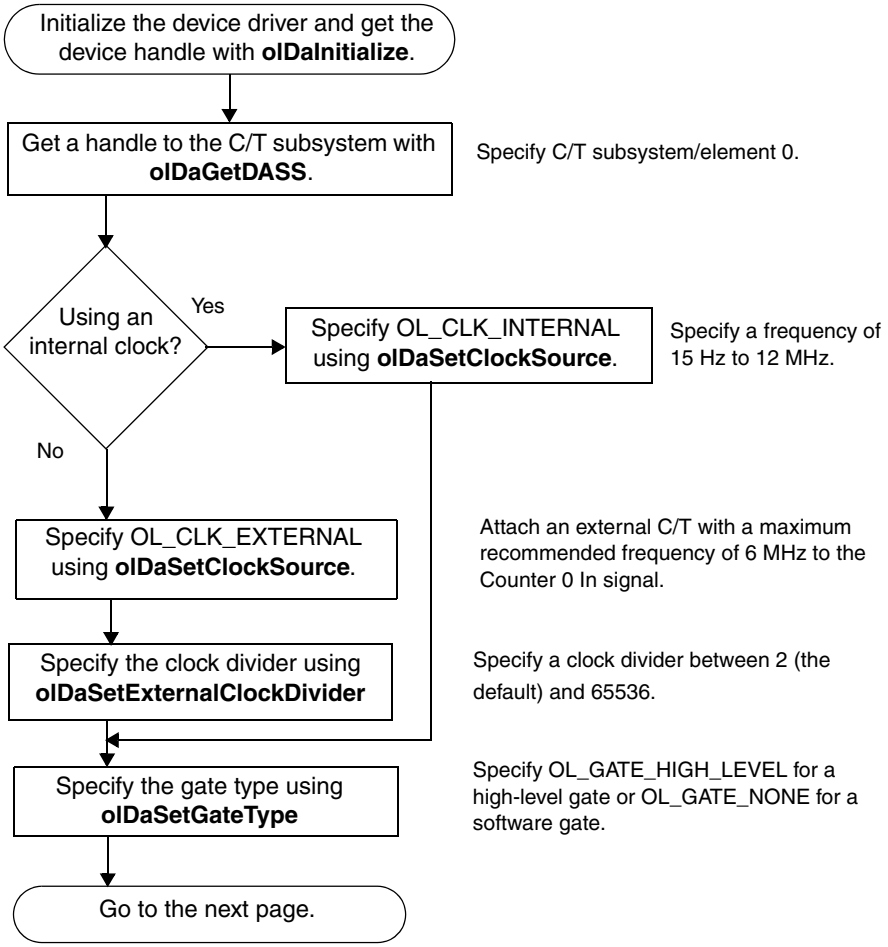
Edge-to-Edge Measurement Operations



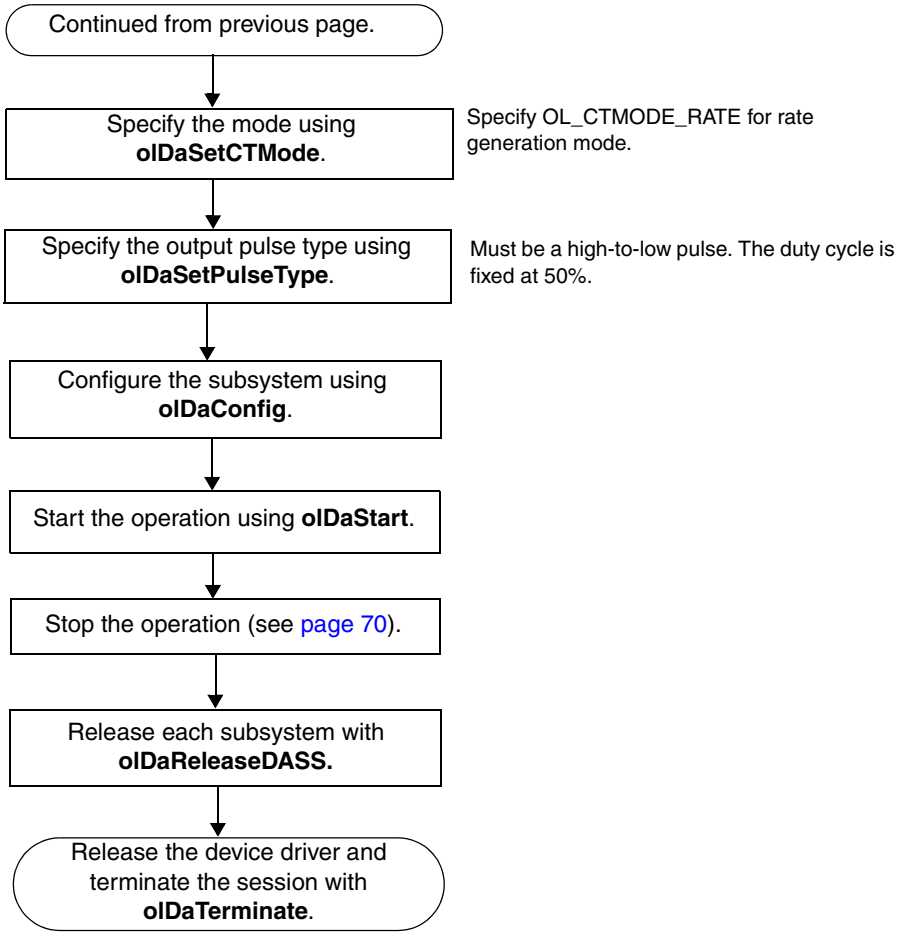
Edge-to-Edge Measurement Operations (cont.)



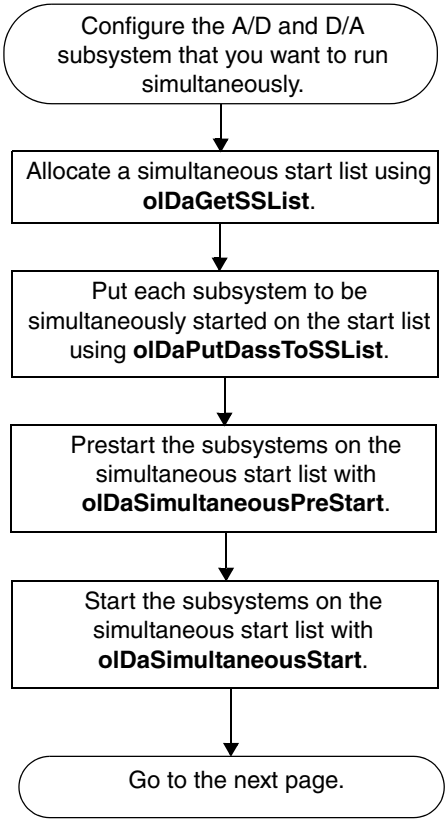
Pulse Output Operations



Pulse Output Operations (cont.)

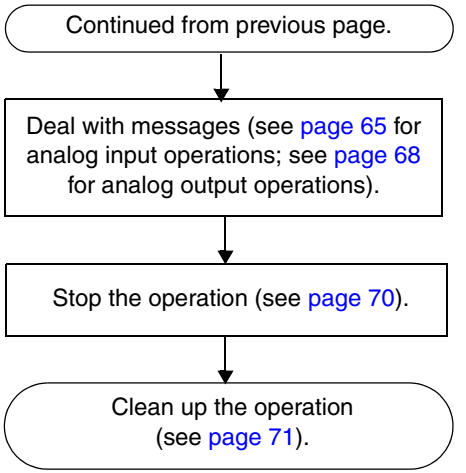


Simultaneous Operations

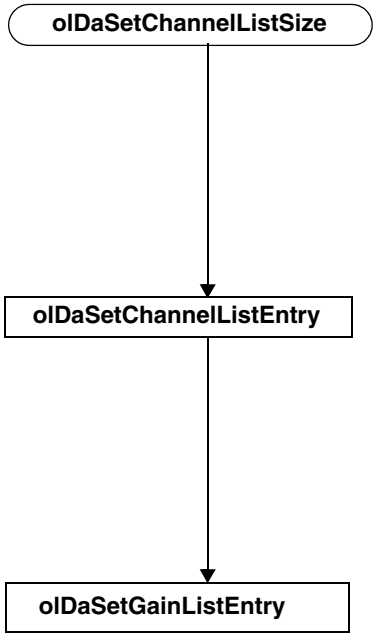


See the previous flow diagrams in this chapter; note that you cannot perform single-value operations simultaneously.

Simultaneous Operations (cont.)



Set Up Channel List and Channel Parameters



Use to specify the size of the analog input channel-gain list (maximum of 16) or analog output channel list (maximum of 2). The default value is 1.

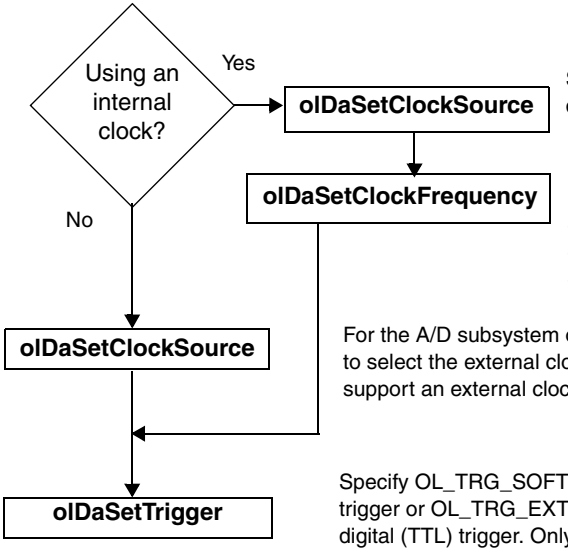
Specify the channels in the A/D or D/A channel list. For the A/D subsystem, channels 0 to 7 are available; you can specify up to 16 channels in the channel-gain list.

For the D/A subsystem, channels 0 and 1 are available; you can specify up to 2 channels in the output-channel list. If you want to update both DACs, enter 0, then 1 in the list.

For the A/D subsystem only, specify the gain for each channel in the channel list (1, 2, 4,or 8).

For the D/A subsystem, use a gain of 1 (the default).

Set Clocks and Triggers



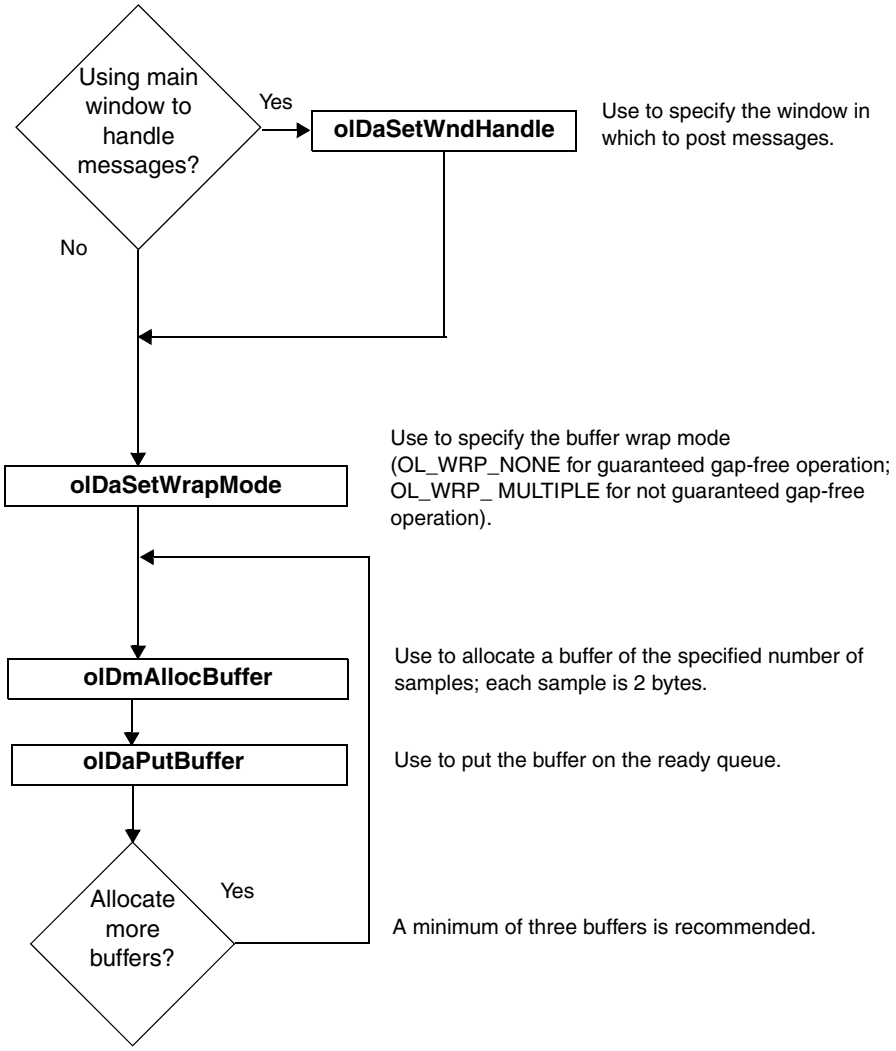
Specify OL_CLK_INTERNAL (the default) to select the internal clock.

Use to specify the frequency of the internal clock. For the A/D and D/A subsystems, values range from 30 Hz to 50 kHz. The driver sets the actual frequency as closely as possible to the number specified.

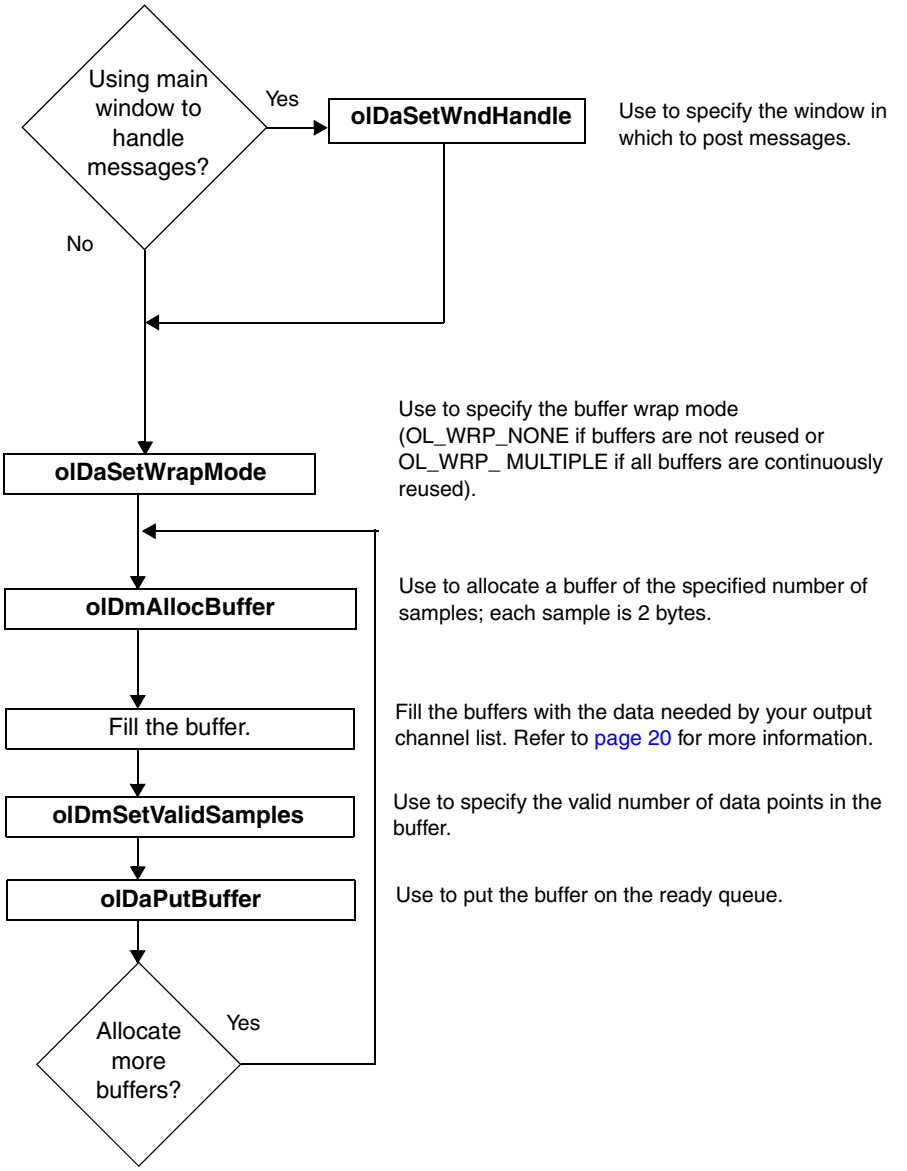
For the A/D subsystem only, specify OL_CLK_EXTERNAL to select the external clock. The D/A subsystem does not support an external clock.

Specify OL_TRG_SOFT (the default) to select a software trigger or OL_TRG_EXTRA to select a falling-edge external digital (TTL) trigger. Only the A/D subsystem supports an external trigger.

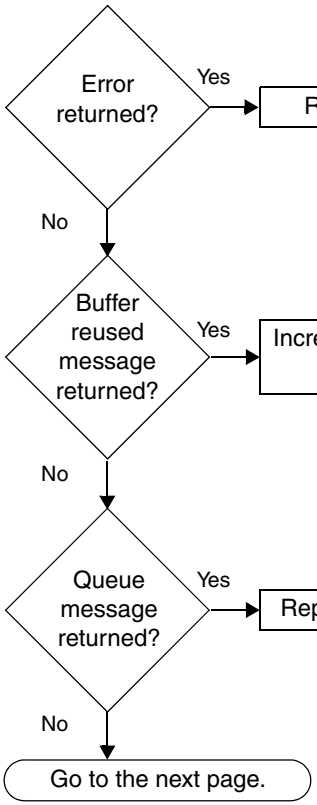
Set Up A/D Buffering



Set Up D/A Buffering



Deal with A/D Messages and Buffers

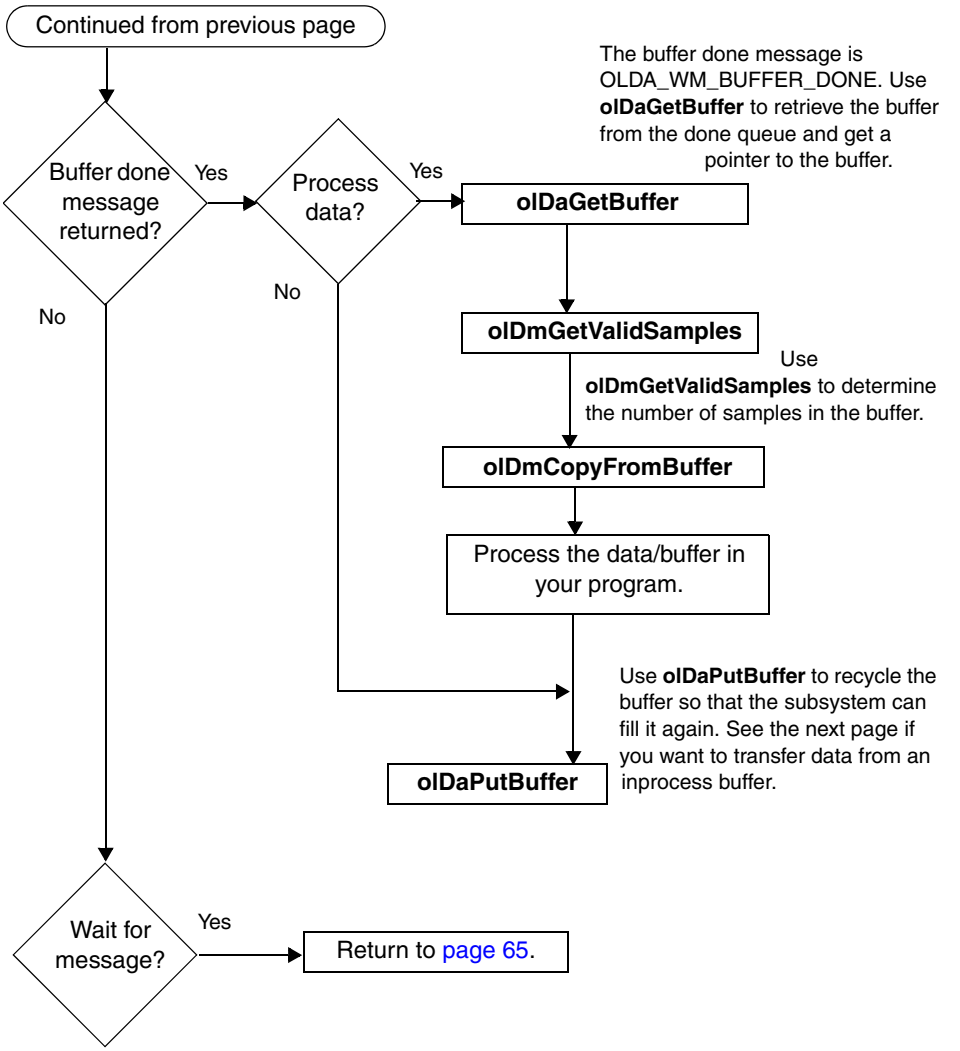


The most likely error message is OLDA_WM_OVERRUN.

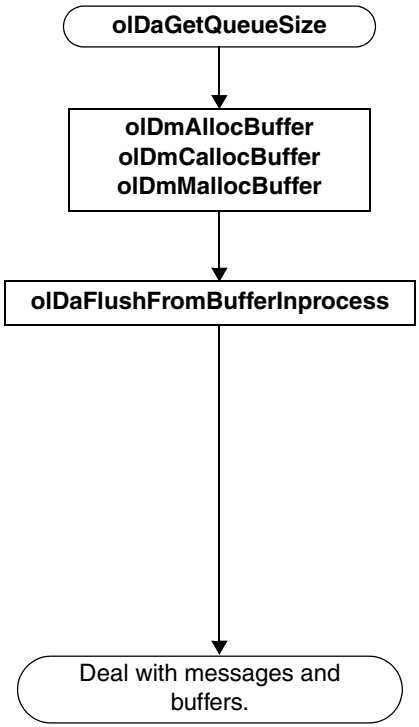
The buffer reused message is OLDA_WM_BUFFER_REUSED.

The queue messages are OLDA_WM_QUEUE_DONE and OLDA_WM_QUEUE_STOPPED. After reporting that the acquisition has stopped, you can clean up the operation (see page 71).

Deal with A/D Messages and Buffers (cont.)



Transfer Data from an Inprocess Buffer



Use to determine the number of buffers on the inprocess queue (at least one must exist).

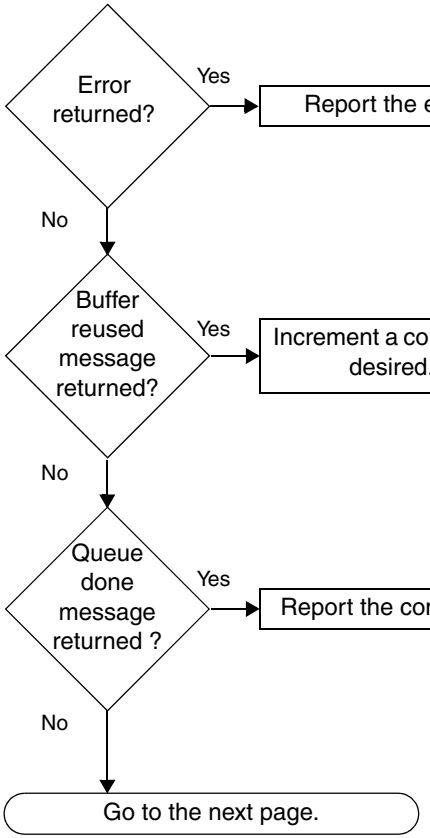
Use to allocate a buffer of the specified number of samples.

Use to copy the data from the inprocess buffer to the allocated buffer for immediate processing.

The buffer into which inprocess data was copied was put onto the done queue by the driver, resulting in an OLDA_WM_BUFFER_DONE message. See page 65 for more information.

When the inprocess buffer has been filled, it too is placed on the done queue and an OLDA_WM_BUFFER_DONE message is posted. However, the number of valid samples is equal to the queue's maximum samples minus what was copied out.

Deal with D/A Messages and Buffers

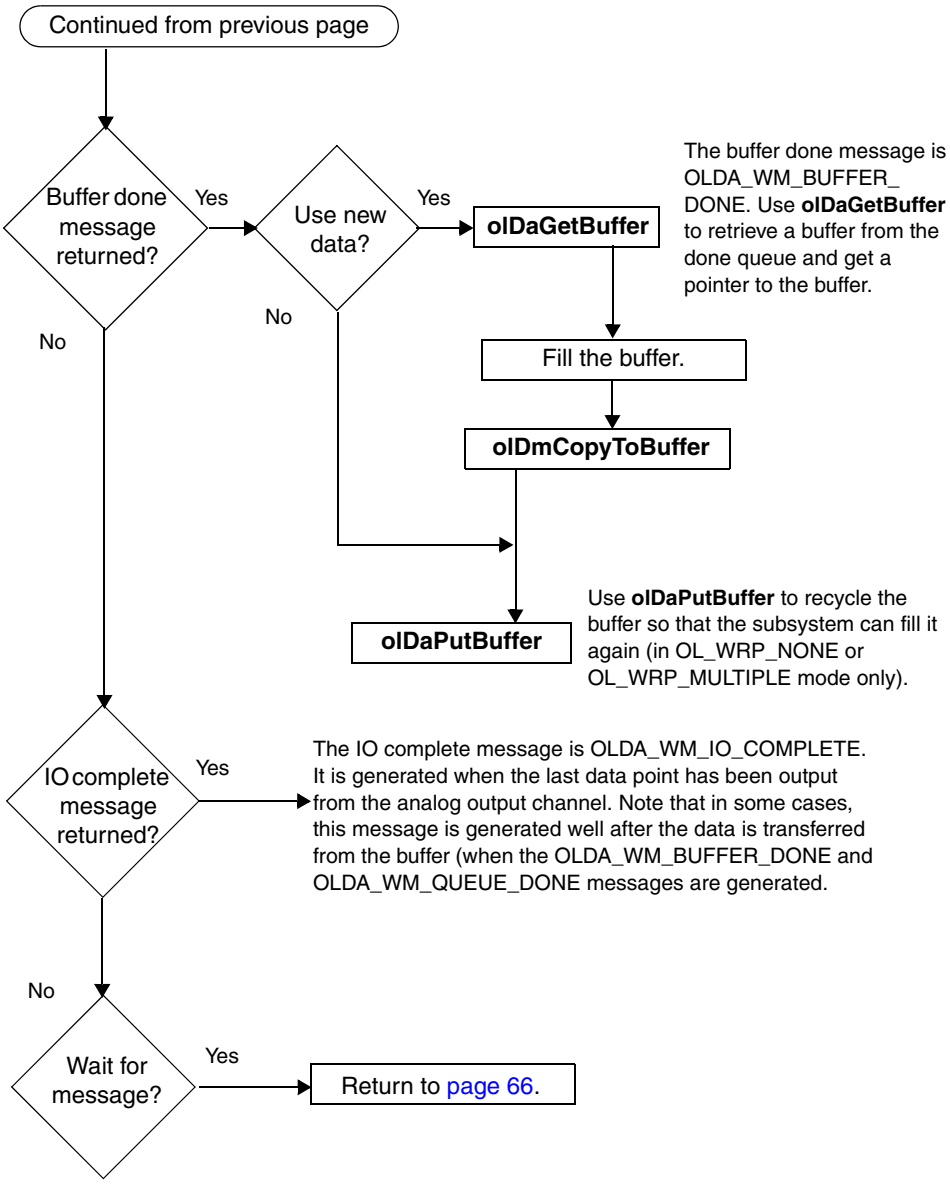


The most likely error messages include OLDA_WM_UNDERRUN and OLDA_WM_TRIGGER_ERROR.

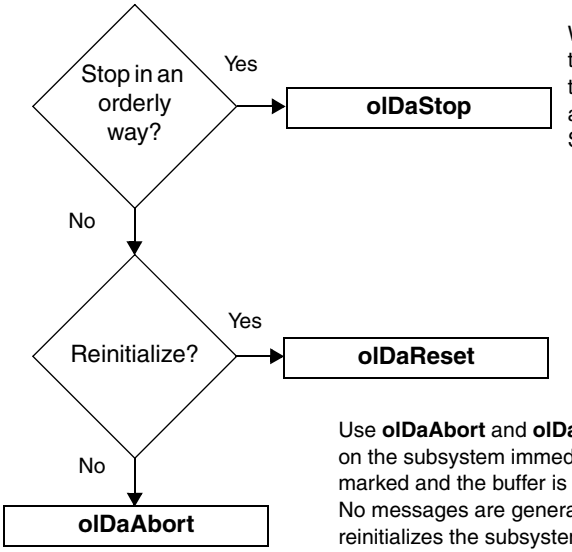
The buffer reused message is OLDA_WM_BUFFER_REUSED.

The queue done messages are OLDA_WM_QUEUE_DONE and OLDA_WM_QUEUE_STOPPED. After reporting that the acquisition has stopped, you can clean up the operation (see page 71).

Deal with D/A Messages and Buffers (cont.)



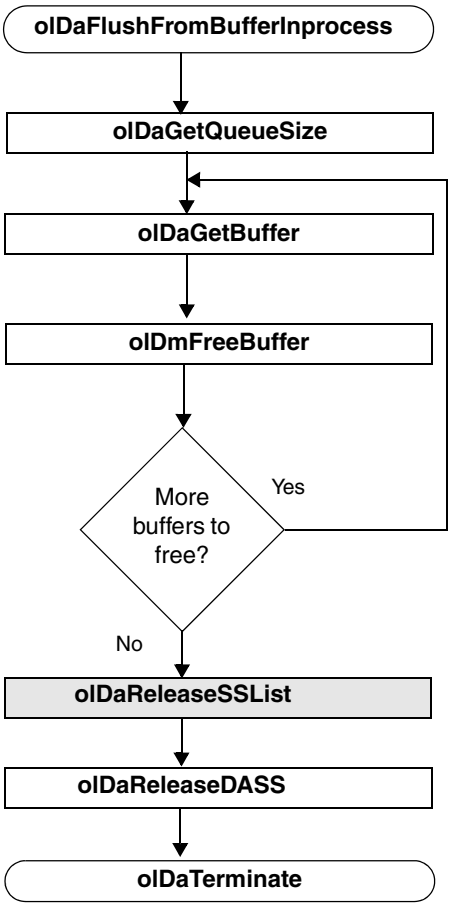
Stop the Operation



Waits until the last sample of the current buffer is filled, then stops. The driver posts a Buffer Done and Queue Stopped message.

Use **olDaAbort** and **olDaReset** to stop the operation on the subsystem immediately; the valid samples are marked and the buffer is placed on the done queue. No messages are generated. In addition, **olDaReset** reinitializes the subsystem to the driver's default state.

Clean Up the Operation



Use to flush all buffers on the ready and/or inprocess queues to the done queue.

Use to determine the number of buffers on the done queue.

Use to retrieve each buffer on the done queue.

Use to free each buffer retrieved from the done queue.

For simultaneous operations only, use to release the simultaneous start list.

Use to release each subsystem.

Use to release the device driver and terminate the session.

Troubleshooting

General Checklist

Should you experience problems using a KUSB-3100 module, please follow these steps:

1. Read all the documentation provided for your product. Make sure that you have added any "Read This First" information to your manual and that you have used this information.
2. Check the CD for any README files and ensure that you have used the latest installation and configuration information available.
3. Check that your system meets the requirements stated in the *KUSB-3100 Getting Started Manual*.
4. Check that you have installed your hardware properly using the instructions in the *KUSB-3100 Getting Started Manual*.
5. Check that you have installed and configured the device driver properly using the instructions in the *KUSB-3100 Getting Started Manual*.

If you still experience problems, try using the information in Table 4 to isolate and solve the problem. If you cannot identify the problem, refer to page 75.

Table 4: Troubleshooting Problems

Symptom	Possible Cause	Possible Solution
Module does not respond.	The module configuration is incorrect.	Check the configuration of your device driver; see the instructions in the *KUSB-3100 Getting Started Manual*.
	The module is damaged.	Contact Keithley for technical support; refer to page 77.
Intermittent operation.	Loose connections or vibrations exist.	Check your wiring and tighten any loose connections or cushion vibration sources; see the instructions in the *KUSB-3100 Getting Started Manual*.
	The module is overheating.	Check environmental and ambient temperature; consult the module's specifications on page 97 of this manual and the documentation provided by your computer manufacturer for more information.
	Electrical noise exists.	Check your wiring and either provide better shielding or reroute unshielded wiring; see the instructions in the *KUSB-3100 Getting Started Manual*.
Device failure error reported.	The module cannot communicate with the Microsoft bus driver or a problem with the bus driver exists.	Check your cabling and wiring and tighten any loose connections; see the instructions in the *KUSB-3100 Getting Started Manual*.
	The module was removed while an operation was being performed.	Ensure that your module is properly connected; see the instructions in the *KUSB-3100 Getting Started Manual*.

Table 4: Troubleshooting Problems (cont.)

Symptom	Possible Cause	Possible Solution
Data appears to be invalid.	An open connection exists.	Check your wiring and fix any open connections; see the instructions in the *KUSB-3100 Getting Started Manual*.
	A transducer is not connected to the channel being read.	Check the transducer connections; see the instructions in the *KUSB-3100 Getting Started Manual*.
	The module is set up for differential inputs while the transducers are wired as single-ended inputs or vice versa.	Check your wiring and ensure that what you specify in software matches your hardware configuration; see the instructions in the *KUSB-3100 Getting Started Manual*.
Computer does not boot.	The power supply of the computer is too small to handle all the system resources.	Check the power requirements of your system resources and, if needed, get a larger power supply; consult the module's specifications on page 97 of this manual.

Service and Support

For the latest tips, software fixes, and other product information, you can always access our World-Wide Web site at the following address: http://www.keithley.com

If you have difficulty using the KUSB-3100 module, Keithley's Technical Support Department is available to provide technical assistance.

For the most efficient service, complete the form on page 78 and be at your computer when you call for technical support. This information helps to identify specific system and configuration-related problems and to replicate the problem in house, if necessary.

Information Required for Technical Support

Name:_____Phone_____
Contract Number: _____
Address: _____
_____

Hardware product(s): _____
serial number: _____
configuration: _____
Device driver: _____ _____
_____ version: _____
Software: _____ _____
serial number: _____ version: _____
PC make/model: _____
operating system: _____ version: _____
Windows version: _____
processor: _____ speed: _____
RAM: _____ hard disk space: _____
network/number of users: _____ disk cache: _____
graphics adapter: _____ data bus: _____

I have the following boards and applications installed in my system: _____
_____
_____
I am encountering the following problem(s): _____
_____
_____
_____
and have received the following error messages/codes: _____
_____
_____
I have run the board diagnostics with the following results: _____
_____
You can reproduce the problem by performing these steps:
1. _____
_____
2. _____
_____
3. _____
_____

Calibration

The KUSB-3100 module is calibrated at the factory and should not require calibration for initial use. It is recommended that you check and, if necessary, readjust the calibration of the analog input and analog output circuitry on the KUSB-3100 modules every six months using the KUSB-3100 Calibration Utility.

Note: Ensure that you installed the KUSB-3100 Device Driver prior to using the KUSB-3100 Calibration Utility. Refer to the *KUSB-3100 Getting Started Manual* for more information on installing the device driver.

This chapter describes how to calibrate the analog input and output subsystems of a KUSB-3100 module using the KUSB-3100 Calibration Utility.

Using the KUSB-3100 Calibration Utility

Start the KUSB-3100 Calibration Utility by performing the following steps:

1. Locate the KUSB-3100 program folder on your hard disk.
2. Double-click **KUSB-3100 Calibration.Exe** in the program folder. *The main menu appears.*
3. Select the module to calibrate, then click **OK**.

Once the KUSB-3100 Calibration Utility is running, you can calibrate the analog input circuitry (either automatically or manually), described on page 82, or the analog output circuitry of the KUSB-3100 module, described on page 85.

Calibrating the Analog Input Subsystem

This section describes how to use the KUSB-3100 Calibration Utility to calibrate the analog input subsystem of a KUSB-3100 module.

Connecting a Precision Voltage Source

To calibrate the analog input circuitry, you need to connect an external precision voltage source to Analog In 0 (AD Ch0) of the KUSB-3100 module.

Using the Auto-Calibration Procedure

Auto-calibration is the easiest to use and is the recommended calibration method. To auto-calibrate the analog input subsystem, perform the following steps:

1. Select the **A/D Configuration** tab of the KUSB-3100 Calibration Utility.
2. Set the voltage supply on AD Ch0 to 0 V.
3. Click **Start Auto Calibration**.
   A message appears notifying you to verify that 0 V is applied to AD Ch0.
4. Check that the supplied voltage to AD Ch0 is 0V, then click **OK**.
   The offset value is calibrated. When the offset calibration is complete, a message appears notifying you to set the input voltage of AD Ch 0 to +9.375 V.
5. Check that the supplied voltage to AD Ch0 is +9.375V, then click **OK**.
   The gain value is calibrated.
6. Click OK to finalize the analog input calibration process.

Note: At any time, you can click **Restore Factory Settings** to reset the A/D calibration values to their original factory settings. This process will undo any auto or manual calibration settings.

Using the Manual Calibration Procedure

If you want to manually calibrate the analog input circuitry instead of auto-calibrating it, perform the following steps:

1. Adjust the offset by performing the following steps:
   a. Verify that 0V is applied to AD Ch0, and that A/D Channel Select is set to Channel 0.
   The current voltage reading for this channel is displayed in the A/D Value window.
   b. Adjust the offset by entering values between 0 and 63 in the Offset edit box, or by clicking the up/down buttons until the A/D Value is 0 V.
2. Adjust the gain by performing the following steps:
   a. Verify that 9.375V is applied to AD Ch0, and that A/D Channel Select is set to Channel 0.
   The current voltage reading for this channel is displayed in the A/D Value window.
   b. Adjust the gain by entering values between 0 and 63 in the Gain edit box, or by clicking the up/down buttons until the A/D Value is 9.3750.

Note: At any time, you can click **Restore Factory Settings** to reset the A/D calibration values to their original factory settings. This process will undo any auto or manual calibration settings.

Once you have finished this procedure, continue with "Calibrating the Analog Output Subsystem" on page 85.

Calibrating the Analog Output Subsystem

This section describes how to use the KUSB-3100 Calibration Utility to calibrate the analog output subsystem of a KUSB-3100 module.

To calibrate the analog output circuitry, you need to connect an external precision voltmeter to analog output channels 0 and 1 of the KUSB-3100 module.

Perform the following steps to calibrate the analog output circuitry:

1. Select the D/A Configuration tab of the KUSB-3100 Calibration Utility.
2. Connect an external precision voltmeter to Analog Output 0 (DAC Ch0) of the KUSB-3100 module.
3. Adjust the offset by entering values between 0 and 63 in the DAC 0 Offset edit box or by clicking the up/down buttons until the voltmeter reads 0 V.
4. Connect an external precision voltmeter to Analog Output 1 (DAC Ch1) of the KUSB-3100 module.
5. Adjust the offset by entering values between 0 and 63 in the DAC 1 Offset edit box or by clicking the up/down buttons until the voltmeter reads 0 V.

Note: At any time, you can click **Restore Factory Settings** to reset the D/A calibration values to their original factory settings. This process will undo any D/A calibration settings.

Once you have finished this procedure, the analog output circuitry is calibrated. To close the KUSB-3100 Calibration Utility, click the close box in the upper, right corner of the window.

Specifications

Table 3 lists the specifications for the A/D subsystem of the KUSB-3100 module.

Table 3: A/D Subsystem Specifications

Feature	KUSB-3100 Specifications
Number of analog input channels	8 single-ended
Number of gains	4 (1, 2, 4, 8)
Resolution	12-bit
Data encoding	twos complement
System accuracy, to % of FSR Gain = 1: Gain = 2: Gain = 4: Gain = 8:	 0.04% 0.06% 0.08% 0.15%
Input Range Gain = 1: Gain = 2: Gain = 4: Gain = 8:	 ±10 V, ±5 V, ±2.5 V, ±1.25 V
Nonlinearity	0.05%
Differential nonlinearity	±1/2 LSB
Inherent quantizing error	1 LSB
Drift Zero: Gain: Differential linearity:	 ±100 µV ±100 ppm monotonic
Input impedance[a] Off channel: On channel:	 10 MΩ, 10 pf 10 MΩ, 100 pf

Table 3: A/D Subsystem Specifications (cont.)

Feature	KUSB-3100 Specifications
Input bias current	±10 nA
Maximum input voltage (without damage) Power on: Power off:	 ±35 V ±20 V
A/D conversion time	8 µs
Channel acquisition time (±½ LSB)	20 µs
Sample-and-hold Aperture uncertainty: Aperture delay:	 2 ns 200 ns
Throughput	50 kHz
ESD protection (per spec) Arc: Contact:	 8 kV 4 kV
Reference	2.5 V
Monotonicity	Yes
Sample Clock Internal: External:	 Yes Yes
Trigger Source Internal: External:	 Yes Yes
A/D Converter Noise	0.6 LSB rms
Channel-to-Channel Offset	0.1 mV

Table 3: A/D Subsystem Specifications (cont.)

Feature	KUSB-3100 Specifications
Effective Number of Bits at 50 kHz with a 1 kHz sine wave:	10.5 bits
Total Harmonic Distortion	< –70 db @ 1 kHz
Channel Crosstalk	–74 db @ 1 kHz
Maximum A/D Pacer Clock Single Analog Input Throughput: Multiple Analog Input Throughput:	 50 kHz 50 kHz

a. Very high input impedance minimizes any source error.

A

Table 4 lists the specifications for the D/A subsystem on the KUSB-3100 module.

Table 4: D/A Subsystem Specifications

Feature	KUSB-3100 Specifications
Number of waveform analog output channels	2
Resolution	12-bit
Data encoding	Twos Complement
Nonlinearity	0.05%
Differential nonlinearity	±1 LSB
Inherent quantizing error	1 LSB
Output range	±10 V
Error Zero: Gain:	 ±4 mV ±0.2%
Drift Zero (bipolar): Gain:	 ±100 µV /° C ±100 ppm
Throughput) Continuously paced analog output mode:	 50 kHz
Current output	±2 mA
Output impedance	<0.2 Ω
Capacitive driver capability	1000 pF minimum
Protection	Short to ground
Power-on voltage	0 V ±10 mV

Table 4: D/A Subsystem Specifications (cont.)

Feature	KUSB-3100 Specifications
Settling time to 0.01% of FSR	20 µs
Slew rate	2 V/ µs
Glitch energy	1 µV -sec
ESD protection (per spec) Arc: Contact:	 8 kV 4 kV
Monotonicity	Yes
Output Clock Internal: External:	 Yes No
Trigger Source Internal: External:	 Yes No

Table 5 lists the specifications for the DIN/DOUT subsystems on the KUSB-3100 module.

Table 5: DIN/DOUT Subsystem Specifications

Feature	KUSB-3100 Specifications
Number of digital I/O lines	16 (8 in/8 out)
Number of ports	2, 8-bit
Input termination	No
Logic family	TTL
Logic sense	Positive true
Inputs Input type: Input logic load: High input voltage: Low input voltage: Low input current:	 Level sensitive 1 TTL Load 2.4 V min 0.8 V max –0.4 mA max
Outputs High output: Low output: High output current (source): Low output current (sink):	 2.8 V min 0.6 V max 2 mA 10 mA
Software I/O selectable	No
ESD protection (per spec) Arc: Contact:	 8 kV 4 kV

Table 6 lists the specifications for the C/T subsystem on the KUSB-3100 module.

Table 6: C/T Subsystem Specifications

Feature	KUSB-3100 Specifications
Number of counter/timers	1
Counter/timer modes	Event counting, frequency measurement, edge-to-edge measurement, rate generation
Resolution	32-bit[a]
Minimum pulse width: (minimum amount of time it takes a C/T to recognize an input pulse)	200 ns
Logic family	TTL
Inputs Input logic load: High input voltage: Low input voltage: Low input current:	Level sensitive 1 TTL Load 2.4 V min 0.8 V max –0.4 mA max
Outputs High output: Low output: High output current (source): Low output current (sink):	 2.8 V min 0.6 V max 2 mA 12 mA
ESD protection (per spec) Arc: Contact:	 8 kV 4 kV

Table 6: C/T Subsystem Specifications (cont.)

Feature	KUSB-3100 Specifications
Internal clock frequency	15 Hz to 12 MHz
External clock divider	2 to 65536

a. The resolution is 16-bits for rate generation mode.

Table 7 lists the specifications for the external A/D trigger on the KUSB-3100 module.

Table 7: External Trigger Specifications

Feature	KUSB-3100 Specifications
Input type	Low-level or falling edge sensitive
Logic family	TTL
Inputs Input logic load: High input voltage: Low input voltage: Low input current:	Level sensitive 1 TTL Load 2.4 V min 0.8 V max –0.4 mA max
Minimum pulse width High: Low:	 200 ns 200 ns
Triggering modes Single scan: Continuous scan:	 Yes Yes

Table 8 lists the specifications for the external A/D clock on the KUSB-3100 module.

Table 8: External Clock Specifications

Feature	KUSB-3100 Specifications
Input type	Rising-edge sensitive
Logic family	TTL
Inputs Input logic load: Input termination: High input voltage: Low input voltage: Low input current:	 Level sensitive 1 TTL Load 2.4 V min 0.8 V max –0.4 mA max
Oscillator frequency	50 kHz maximum
Minimum pulse width High: Low:	 200 ns 200 ns

Table 9 lists the power, physical, and environmental specifications for the KUSB-3100 module.

Table 9: Power, Physical, and Environmental Specifications

Feature	KUSB-3100 Specifications
Power +5 V Enumeration Operation	<100 mA <250 mA
Physical Dimensions (board): Dimensions (box with screw terminals and feet): Weight (board): Weight (box with screw terminals and feet):	 100 mm (L) x 100 mm (W) x 15.5 mm (H) 107.7 mm (L) x 100 mm (W) x 33.5 mm (H) 65.3 g 138.4 g
Environmental Operating temperature range: Storage temperature range: Relative humidity:	 0 to 70° C –40 to 125° C to 95% non-condensing

Connector Pin Assignments

Table 10 lists the screw terminal assignments for the KUSB-3100 module.

Table 10: KUSB-3100 Screw Terminal Assignments

Screw Terminal	Signal	Screw Terminal	Signal
20	USB +5 V Out	40	Ext Trig In
19	Ground	39	Ext Clock In
18	Counter 0 In	38	Ground
17	Counter 0 Out	37	Digital Output 7
16	Counter 0 Gate	36	Digital Output 6
15	Ground	35	Digital Output 5
14	DAC 1	34	Digital Output 4
13	DAC 1 Return	33	Digital Output 3
12	DAC 0	32	Digital Output 2
11	DAC 0 Return	31	Digital Output 1
10	2.5 V Reference	30	Digital Output 0
9	Analog Ground	29	Ground
8	Analog Input CH7 High	28	Digital Input 7
7	Analog Input CH6 High	27	Digital Input 6
6	Analog Input CH5 High	26	Digital Input 5
5	Analog Input CH4 High	25	Digital Input 4
4	Analog Input CH3 High	24	Digital Input 3
3	Analog Input CH2 High	23	Digital Input 2
2	Analog Input CH1 High	22	Digital Input 1
1	Analog Input CH0 High	21	Digital Input 0

Reading from or Writing to the Digital Registers

If you want to read the value of the digital input lines or write to the digital output lines quickly and do not want to use DT-Open Layers to do this, you can use the following API functions:

- **olReadReg**, described on page 103.
- **olWriteReg**, described on page 105.

These functions access the registers of the module directly.

olReadReg

Syntax

```
ECODE olReadReg (
    HDEV hDev,
    ULNG Address,
    PULNG pData);
```

Include File

oldadefs.h
oldaapi.h

Description

Reads data directly from the digital registers of the module.

Parameters

Name: hDev

Description: A variable of type HDEV that specifies the handle to the device.

Name: Address

Description: An unsigned long variable that specifies the base address of the desired register.

Values are as follows:

- **DIO_PORT_CONFIG –** Port configuration register.
- **DIO_PORT_DATA –** Port data register.

Name:	pData
Description:	A pointer to a unsigned long variable in which the data from the specified register is returned. Values can range from 0 to 4,294,967,295. If DIO_PORT_CONFIG is specified for *Address*, the value of the variable pointed to by *pData* is the bit mask that specifies the configuration of the digital I/O lines, where bits that have "0" values are input lines and bits that have "1" values are output lines. If DIO_PORT_Data is specified for *Address*, the value of the variable pointed to by *pData* represents the state of the digital input lines.
Notes	The KUSB-3100 module has 8 fixed digital input lines and 8 fixed digital output lines.
Return Values	Possible return values are as follows:
OLBADRANGE	The value is out of range for the device.
OLNOTSUPPORTED	Request not supported by subsystem.
OLBADDEVHANDLE	Illegal device handle specified.

olWriteReg

Syntax

```
ECODE olWriteReg (
    HDEV hDev,
    ULNG Address,
    ULNG DataVal);
```

Include File

oldadefs.h
oldaapi.h

Description

Writes values directly to the digital registers of the module.

Parameters

Name: hDev

Description: A variable of type HDEV that specifies the handle to the device.

Name: Address

Description: An unsigned long variable that specifies the base address of the hardware register to write to.

Values are as follows:

- **DIO_PORT_CONFIG –** Port configuration register.
- **DIO_PORT_DATA –** Port data register.

Name:	DataVal
Description:	An unsigned long variable that contains the digital output value to write the specified register. Values can range between 0 and 4,294,967,295. If DIO_PORT_CONFIG is specified for *Address*, the value specified for *DataVal* is the bit mask that configures the digital I/O lines for input (0) or output (1). If DIO_PORT_Data is specified for *Address*, the value specified for *DataVal* is the value that is written to the configured digital output lines.
Notes	The KUSB-3100 module has 8 fixed digital input lines and 8 fixed digital output lines.
Return Values	Possible return values are as follows:
OLBADRANGE	The value is out of range for the device.
OLNOTSUPPORTED	Request not supported by subsystem.
OLBADDEVHANDLE	Illegal device handle specified.

Index

D

E

F

G

H

I

L

M

N

O

P

Q

R

S

T

U

V

W

Z

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12/04